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Rocky Mountain Arsenal
Commerce City
Adams County
Colorado

HAER No. CO-21

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Department of the Interior
Washington, DC 20013-7127

HAER
COLO,
1-COMCI,
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HISTORIC AMERICAN ENGINEERING RECORD

Rocky Mountain Arsenal

CO-21

| | |
|---|---|
| Location: | In Adams County, Colorado, north of Denver in Commerce City. |
| Date of Construction: | Established in 1942 |
| Owner: | Department of the Army |
| Significance: | Established during World War II to manufacture chemical weapons and incendiary mmunitons. Since 1950 its principal activities have related to the manufacture, munitions-leading, and disposal of nerve agent GB. |
| Historical Report Prepared by: | Jeffrey A. Hess, 1984. |
| Prepared for Transmittal by: | Robie S. Lange, HABS/HAER, 1985. |

# EXECUTIVE SUMMARY

Rocky Mountain Arsenal (RMA) is part of the Army's Armament, Munitions and Chemical Command (AMCCOM). The arsenal is a government-owned-and-operated installation occupying 17,238 acres in Commerce City, Colorado, just north of Denver. Constructed in 1942 to manufacture war gases, RMA was soon expanded for the production of incendiary munitions. After V-J Day, the installation was designated a standby facility, and much of its chemical plant was leased to private industry -- an arrangement that continues to the present day. Although RMA was reactivated for incendiary production during the Korean and Vietnam wars, its principal activities since 1950 have been the manufacture, munitions-loading, and disposal of nerve agent GB. These operations have centered in a GB production-and-filling complex constructed in 1953 and partially converted into a detoxification center in the 1970s. At present, the nerve-agent manufacturing and filling lines are in standby status; the detoxification center is in active use.

RMA comprises 299 buildings, about half of which date from the 1940s. The installation also contains three farmhouses (Buildings T-131, T-373, T-831) and a garage (T-831-A) that were acquired with the site. Constructed sometime between 1910 and 1930, these structures contribute to a general understanding of the area's pre-military history, but they are not of specific architectural or historical significance. Because the arsenal's original production lines have been removed and many of its original buildings remodeled, the installation no longer retains the architectural and technological character of a World War II installation. There are no Category I, Category II, or Category III historic properties at RMA.

CONTENTS

# PREFACE

This report presents the results of an historic properties survey of the Rocky Mountain Arsenal (RMA). Prepared for the United States Army Materiel Development and Readiness Command (DARCOM), the report is intended to assist the Army in bringing this installation into compliance with the National Historic Preservation Act of 1966 and its amendments, and related federal laws and regulations. To this end, the report focuses on the identification, evaluation, documentation, nomination, and preservation of historic properties at the RMA. Chapter 1 sets forth the survey's scope and methodology; Chapter 2 presents an architectural, historical, and technological overview of the installation and its properties; and Chapter 3 identifies significant properties by Army category and sets forth preservation recommendations. Illustrations and an annotated bibliography supplement the text.

This report is part of a program initiated through a memorandum of agreement between the National Park Service, Department of the Interior, and the U.S. Department of the Army. The program covers 74 DARCOM installations and has two components: 1) a survey of historic properties (districts, buildings, structures, and objects), and 2) the development of archaeological overviews. Stanley H. Fried, Chief, Real Estate Branch of Headquarters DARCOM, directed the program for the Army, and Dr. Robert J. Kapsch, Chief of the Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER) directed the program for the National Park Service. Sally Kress Tompkins was program manager, and Robie S. Lange was project manager for the historic properties survey. Technical assistance was provided by Donald C. Jackson.

Building Technology Incorporated acted as primary contractor to HABS/HAER for the historic properties survey. William A. Brenner was BTI's principal-in-charge and Dr. Larry D. Lankton was the chief technical consultant. Major subcontractors were the MacDonald and Mack Partnership and Jeffrey A. Hess. The author of this report was Jeffrey A. Hess. The author would like to thank the many employees at RMA who graciously assisted him in his research and field surveys. He especially acknowledges the help of Tom Donnelly, Public Affairs Officer; Dr. William McNeill, Director of Technical Operations; Jim L. Green, Facilities Engineer; and Darlene Puleo, Management Assistant.

The complete HABS/HAER documentation for this installation will be included in the HABS/HAER collections at the Library of Congress, Prints and Photographs Division, under the designation HAER No. CO-21.

# Chapter 1

# INTRODUCTION

## SCOPE

This report is based on an historic properties survey conducted in September 1983 of all Army-owned properties located within the official boundaries of the Rocky Mountain Arsenal (RMA). The survey included the following tasks:

- Completion of documentary research on the history of the installation and its properties.

- Completion of a field inventory of all properties at the installation.

- Preparation of a combined architectural, historical, and technological overview for the installation.

- Evaluation of historic properties and development of recommendations for preservation of these properties.

Also completed as a part of the historic properties survey of the installation, but not included in this report, are HABS/HAER Inventory cards for 23 individual properties. These cards, which constitute HABS/HAER Documentation Level IV, will be provided to the Department of the Army. Archival copies of the cards, with their accompanying photographic negatives, will be transmitted to the HABS/HAER collections at the Library of Congress.

The methodology used to complete these tasks is described in the following section of this report.

## METHODOLOGY

### 1. Documentary Research

RMA was constructed in 1942 to manufacture toxic and incendiary munitions. Since the arsenal was one of four government-owned-and-operated installations involved in such activities during World War II, an evaluation of its historical significance requires a general understanding of the country's chemical-warfare manufacturing program. To identify relevant published sources, research on chemical munitions was conducted in standard bibliographies of military history, engineering, and the applied sciences. Unpublished sources were identified by researching the historical and technical archives of the U. S. Army Armament, Munitions and Chemical Command (AMCCOM) at Rock Island Arsenal.[1]

In addition to such industry-wide research, a concerted effort was made to locate sources dealing specifically with the history and technology of RMA. This site-specific research was conducted primarily at the AMCCOM Historical Office at Rock Island Arsenal; the Denver Public Library in Denver, Colorado; and the government's administrative and engineering archives at RMA. The Colorado State Historic Preservation Office (Colorado Heritage Center, Denver) was also contacted for information on the architecture, history, and technology of RMA, but had no pertinent data.

Army records used for the field inventory included current Real Property Inventory (RPI) printouts that listed all officially recorded buildings and structures by facility classification and date of construction; the installation's property record cards; base maps and photographs supplied by installation personnel; and installation master planning, archaeological, environmental assessment, and related reports and documents. A complete listing of this documentary material may be found in the bibliography.

2. Field Inventory

Architectural and technological field surveys were conducted in September 1983 by Jeffrey A. Hess. Following discussions with Tom Donnelly, Public Affairs Officer, and Jim L. Green, Facilities Engineer, the surveyor inspected major manufacturing and demilitarization facilities and completed a general field survey of all exterior areas at the installation. Tom Donnelly served as escort.

Field inventory procedures were based on the HABS/HAER Guidelines for Inventories of Historic Buildings and Engineering and Industrial Structures.[2] All areas and properties were visually surveyed. Building locations and approximate dates of construction were noted from the installation's property records and field-verified. Interior surveys were made of the major facilities to permit adequate evaluation of architectural features, building technology, and production equipment.

Field inventory forms were prepared for, and black and white 35 mm photographs taken of all buildings and structures through 1945 except basic utilitarian structures of no architectural, historical, or technological interest. When groups of similar ("prototypical") buildings were found, one field form was normally prepared to represent all buildings of that type. Field inventory forms were also completed for representative post-1945 buildings and structures.[3] Information collected on the field forms was later evaluated, condensed, and transferred to HABS/HAER Inventory cards.

3. Historical Overview

A combined architectural, historical, and technological overview was prepared from information developed from the documentary research and the field inventory. It was written in two parts: 1) an introductory description of the installation, and 2) a history of the installation by periods of development, beginning with pre-military land uses. Maps and photographs were selected to supplement the text as appropriate.

The objectives of the overview were to 1) establish the periods of major construction at the installation, 2) identify important events and individuals associated with specific historic properties, 3) describe patterns and locations of historic property types, and 4) analyze specific building and industrial technologies employed at the installation.

4. Property Evaluation and Preservation Measures

Based on information developed in the historical overviews, properties were first evaluated for historical significance in accordance with the eligibility criteria for nomination to the National Register of Historic Places. These criteria require that eligible properties possess integrity of location, design, setting, materials, workmanship, feeling, and association, and that they meet one or more of the following:[4]

A. Are associated with events that have made a significant contribution to the broad patterns of our history.

B. Are associated with the lives of persons significant in the nation's past.

C. Embody the distinctive characteristics of a type, period, or method of construction, represent the work of a master, possess high artistic values, or represent a significant and distinguishable entity whose components may lack individual distinction.

D. Have yielded, or may be likely to yield, information important in pre-history or history.

Properties thus evaluated were further assessed for placement in one of five Army historic property categories as described in Army Regulation 420-40:[5]

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|---|---|
| Category I | Properties of major importance |
| Category II | Properties of importance |
| Category III | Properties of minor importance |
| Category IV | Properties of little or no importance |
| Category V | Properties detrimental to the significance of adjacent historic properties. |

Based on an extensive review of the architectural, historical, and technological resources identified on DARCOM installations nationwide, four criteria were developed to help determine the appropriate categorization level for each Army property. These criteria were used to assess the importance not only of properties of traditional historical interest, but also of the vast number of standardized or prototypical buildings, structures and production processes that were built and put into service during World War II, as well as of properties associated with many post-war technological achievements. The four criteria were often used in combination and are as follows:

1) <u>Degree of importance as a work of architectural, engineering, or industrial design</u>. This criterion took into account the

qualitative factors by which design is normally judged: artistic merit, workmanship, appropriate use of materials, and functionality.

2) Degree of rarity as a remaining example of a once widely used architectural, engineering, or industrial design or process. This criterion was applied primarily to the many standardized or prototypical DARCOM buildings, structures, or industrial processes. The more widespread or influential the design or process, the greater the importance of the remaining examples of the design or process was considered to be. This criterion was also used for non-military structures such as farmhouses and other once prevalent building types.

3) Degree of integrity or completeness. This criterion compared the current condition, appearance, and function of a building, structure, architectural assemblage, or industrial process to its original or most historically important condition, appearance, and function. Those properties that were highly intact were generally considered of greater importance than those that were not.

4) Degree of association with an important person, program, or event. This criterion was used to examine the relationship of a property to a famous personage, wartime project, or similar factor that lent the property special importance.

The majority of DARCOM properties were built just prior to or during World War II, and special attention was given to their evaluation. Those that still remain do not often possess individual importance, but collectively they represent the remnants of a vast construction undertaking whose architectural, historical, and technological importance needed to be assessed before their numbers diminished further. This assessment centered on an extensive review of the military construction of the 1940-1945 period, and its contribution to the history of World War II and the post-war Army landscape.

Because technology has advanced so rapidly since the war, post-World War II properties were also given attention. These properties were evaluated in terms of the nation's more recent accomplishments in weaponry, rocketry, electronics, and related technological and scientific endeavors. Thus the traditional definition of "historic" as a property 50 or more years old was not germane in the assessment of either World War II or post-war DARCOM buildings and structures; rather, the historic importance of all properties was evaluated as completely as possible regardless of age.

Property designations by category are expected to be useful for approximately ten years, after which all categorizations should be reviewed and updated.

Following this categorization procedure, Category I, II, and III historic properties were analyzed in terms of:

- Current structural condition and state of repair. This information was taken from the field inventory forms and photographs, and was often supplemented by rechecking with facilities engineering personnel.

- The nature of possible future adverse impacts to the property. This information was gathered from the installation's master planning documents and rechecked with facilities engineering personnel.

Based on the above considerations, the general preservation recommendations presented in Chapter 3 for Category I, II, and III historic properties were developed. Special preservation recommendations were created for individual properties as circumstances required.

5. Report Review

Prior to being completed in final form, this report was subjected to an in-house review by Building Technology Incorporated. It was then sent in draft to the subject installation for comment and clearance and, with its associated historical materials, to HABS/HAER staff for technical review. When the installation cleared the report, additional draft copies were sent to DARCOM, the appropriate State Historic Preservation Officer, and, when requested, to the archaeological contractor performing parallel work at the installation. The report was revised based on all comments collected, then published in final form.

NOTES

1. The following bibliographies of published sources were consulted: Industrial Arts Index, 1938-1957; Applied Science and Technology Index, 1958-1980; Engineering Index, 1938-1983; Robin Higham, ed., A Guide to the Sources of United States Military History (Hamden, Conn.: Archon Books, 1975); John E. Jessup and Robert W. Coakley, A Guide to the Study and Use of Military History (Washington, D.C.: U.S. Government Printing Office, 1979); "Military Installations," Public Works History in the United States, eds., Suellen M. Hoy and Michael C. Robinson (Nashville: American Association for State and Local History, 1982), pp. 380-400. AMCCOM (formerly ARRCOM, or U.S. Army Materiel Readiness Command) is the military agency responsible for supervising the operation of government-owned munititions plants; its headquarters are located at Rock Island Arsenal, Rock Island, Illinois. Although there is no comprehensive index to AMCCOM archival holdings, the agency's microfiche collection of unpublished reports is itemized in ARRCOM, Catalog of Common Sources, Fiscal Year 1983, 2 vols. (no pl.: Historical Office, AMCCOM, Rock Island Arsenal, n.d.).

2. Historic American Buildings Survey/Historic American Engineering Record, National Park Service, Guidelines for Inventories of Historic Buildings and Engineering and Industrial Structures (unpublished draft, 1982).

3. Representative post-World War II buildings and structures were defined as properties that were: (a) "representative" by virtue of construction type, architectural type, function, or a combination of these, (b) of obvious Category I, II, or III historic importance, or (c) prominent on the installation by virtue of size, location, or other distinctive feature.

4. National Park Service, How to Complete National Register Forms (Washington, D.C.: U.S. Government Printing Office, January 1977).

5. Army Regulation 420-40, Historic Preservation (Headquarters, U.S. Army: Washington, D.C., 15 April 1984).

# Chapter 2

# HISTORICAL OVERVIEW

## BACKGROUND

Rocky Mountain Arsenal (RMA) is a government-owned-and-operated installation occupying a 17,238-acre site in Commerce City, Colorado, just north of Denver. Constructed in 1942 to manufacture war gases, the arsenal was soon expanded for the production of incendiary munitions. After V-J Day, RMA was designated a standby facility, and much of its chemical plant was leased to private industry -- an arrangement that continues to the present day. Although RMA was reactivated for incendiary production during the Korean and Vietnam wars, its principal activities since 1950 have been the manufacture, munitions-loading, and disposal of nerve agent GB. These operations have centered in a GB production-and-filling complex constructed in 1953 and partially converted into a detoxification center in the 1970s. Currently, RMA comprises 299 buildings, about half of which date from the World War II period. Because the arsenal's original production lines have been removed and many of its original buildings remodeled, the installation no longer retains the architectural and technological character of a World War II installation. The nerve-agent manufacturing and filling lines are in standby status; the detoxification center is in active use.

## WORLD WAR II

In common parlance, the term "chemical warfare" is most closely associated with the use of toxic substances, especially poison gases. By military definition, however, the term applies equally to the deployment of incendiary and smoke devices. During World War I, the United States produced all three types of chemical munitions at Edgewood Arsenal in Maryland, under the supervision of the newly created Chemical Warfare Service. Edgewood Arsenal remained the country's primary chemical-warfare installation until World War II, when Congress authorized the construction of three additional plants: Huntsville Arsenal in Huntsville, Alabama; Pine Bluff Arsenal in Pine Bluff, Arkansas; and RMA in Commerce City, Colorado.[1]

## Site Selection and Former Land Use

The selection of the RMA site was governed by the same basic criteria used in evaluating locations for all three of the new chemical-warfare arsenals. These considerations included:

1) a mid-continental location as a defense against enemy bombardment
2) proximity to main railroad lines
3) availability of an ample water supply and sufficient electrical power for processing purposes
4) availability of suitable labor[2]

Located in Commerce City, Colorado, only a few miles north of Denver, the RMA site satisfied all selection criteria. The City of Denver housed a sizeable industrial work force and was a major distribution center for rail freight and electrical power. The area's hydrology also assured an abundance of well and river water for industrial purposes. When the federal government took possession of the 19,883-acre site in the spring of 1942, the installation contained about 700 farm buildings on a patchwork of cropland, pasture, and underbrush.[3] Only three houses (Buildings T-131, T-373, T-831) and a garage (Building T-831-A) survive at the arsenal from this earlier period. Constructed sometime between 1910 and 1930, these structures are of modest size and unassuming design.

## Construction

RMA was the last of the chemical-warfare plants to be built during World War II, and it profited from the experience of its predecessor installations. This was especially true in terms of the construction team. The same personnel that designed and built Huntsville Arsenal in Alabama repeated their roles for the RMA project: Colonel Carl H. Breitweiser of the Corps of Engineers as Area Engineer; Whitman, Requart and Smith of Baltimore as architect-engineer; and Kershaw, Swinerton and Walberg of San Francisco and Birmingham, Alabama, as prime contractor.[4]

All three World-War-II, chemical-warfare arsenals employed a similar utilitarian-industrial architecture that made extensive use of clay tile, transite, and wood framing. RMA, however, was unique in its overall design. At the other arsenals, manufacturing operations were scattered throughout the installations. At RMA, they were restricted to a 260-acre tract in the center of the plant, which resulted in a "[more] efficient and economic operation."[5] This centralized area was originally designed for the production and bulk loading of two war gases lewisite (dichlor-2-chloro-vinyl-arsine) and mustard (dichloroethyl sulfide). Lewisite manufacturing took place in Buildings 511, 511A, 514, 514A, 515, and 516; mustard manufacturing in Buildings 412, 414, 422, 424, 425, 429, and 431. In addition to these facilities, the area also contained manufacturing plants for the following intermediate chemicals used in lewisite and/or mustard production: acetylene (Building 522), arsenic trichloride (Building 523), chlorine (Buildings 242, 243, 244, 247, 248, 249, 251, 254, 255), ethylene (Buildings 431, 433, 434, 435, 461, 462A, 463), sulfur monochloride (Building 411), and thionyl chloride (Buildings 471, 472, 473). To the east of the manufacturing area, there was a maintenance-and-storage area (600-series buildings), a cantonment area for Chemical Warfare Service personnel (Buildings 151-167), and a headquarters compound containing the post's Administration Building (Building 111) and Communications Building (Building 112). To the west of the manufacturing area, there was a small grouping of magazines (870-, 880-series buildings) (Figures 1-9).

Construction activities at RMA commenced in June 1942, and on January 1, 1943, the arsenal produced its first batch of mustard gas. The new year inaugurated a new construction program for a napalm bomb plant (Buildings 741-749), which was completed, just east of the manufacturing area, in the spring of 1943. Additional napalm-bomb manufacturing facilities (Buildings 731, 732) were authorized in the spring of 1945 and completed shortly after V-J Day (Figures 10, 11). At that time, the arsenal numbered approximately 280 buildings.[6]

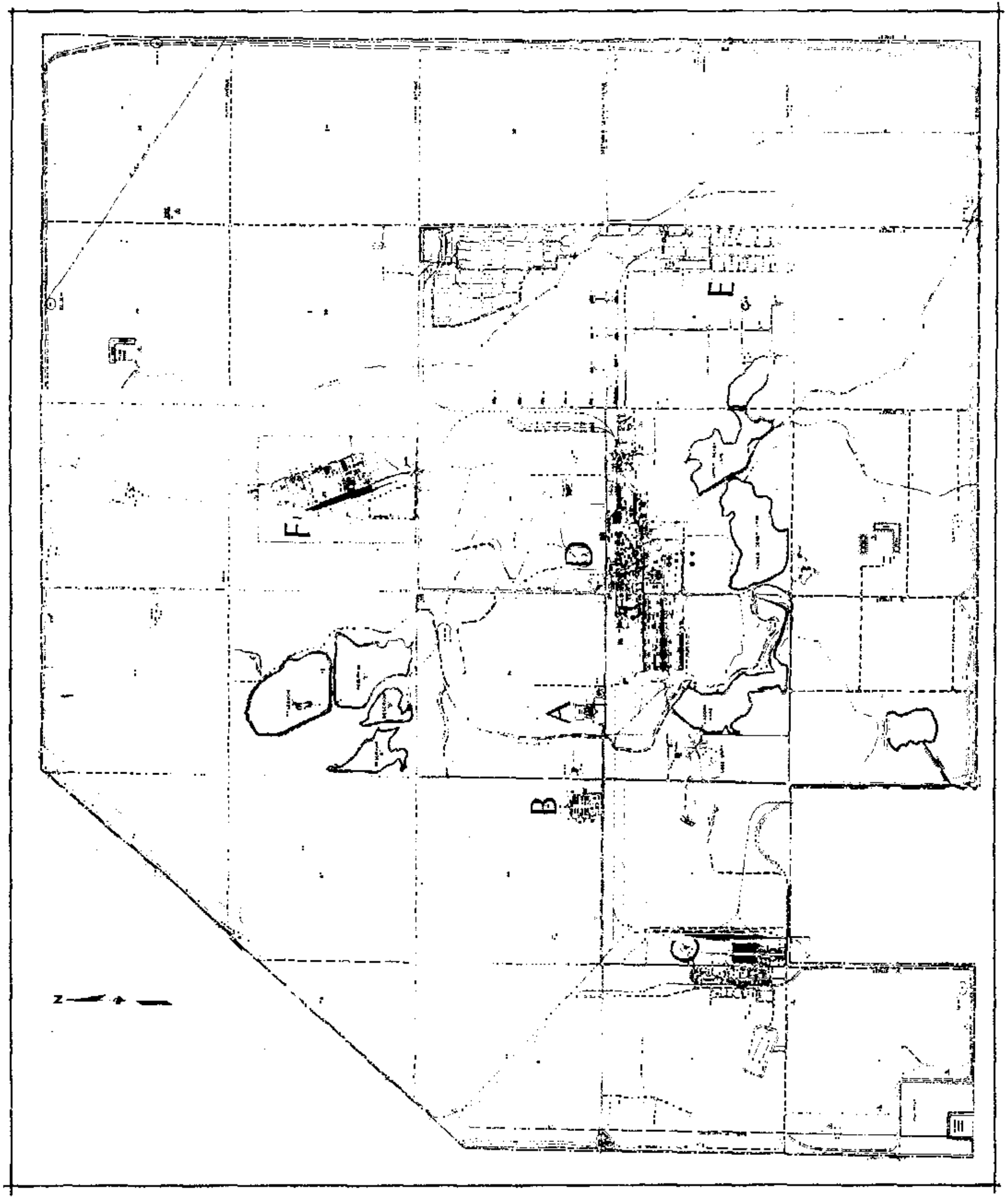


Figure 1: Installation site plan (Source: Facilities Engineer's Office Archives, RMA).

A. Administration area.
B. Cantonment area.
C. Shop-and-storage area.
D. Chemical-manufacturing area.
E. Magazine area.
F. Nerve-agent production and demilitarization area.

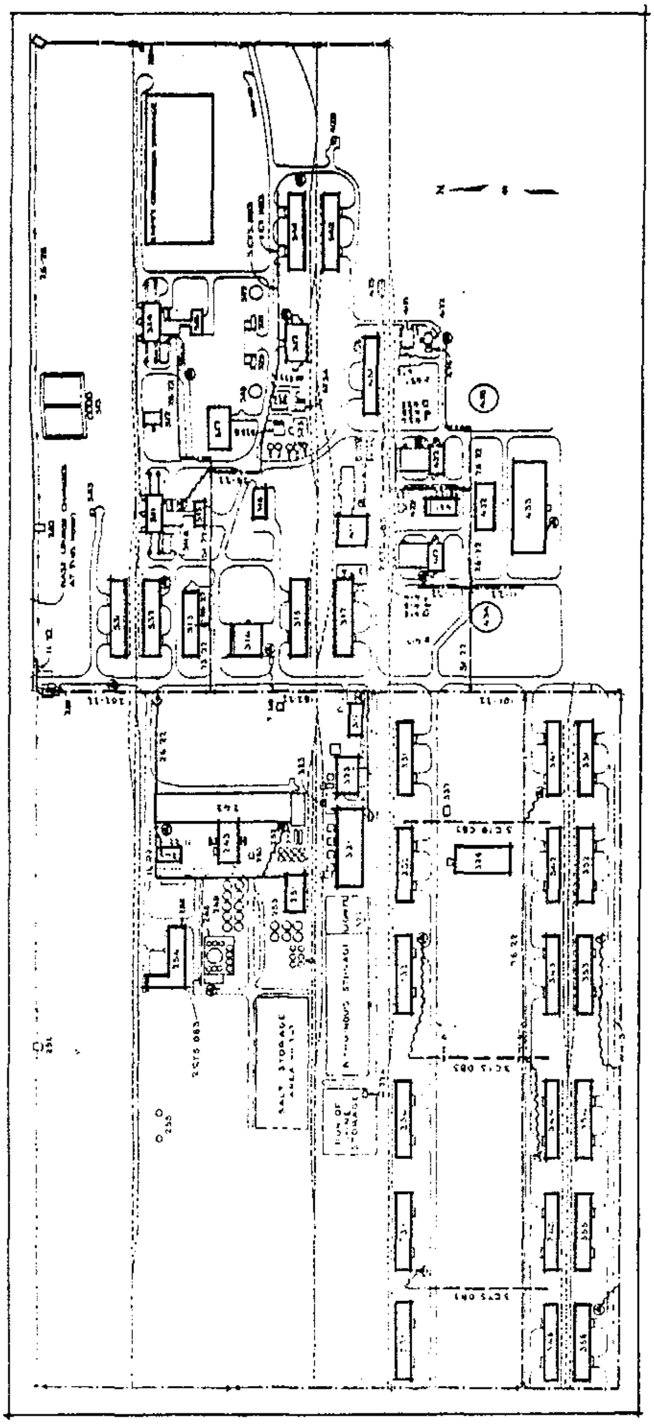

Figure 2: Chemical-manufacturing area (Source: Armed Service Forces, Chemical Warfare Service, "History of Rocky Mountain Arsenal," vol. 1, unpublished report, 1945, RMA Administrative Archives).

Figure 3: Aerial view of the chemical-manufacturing area, looking northeast, c. 1980 (Source: RMA Public Affairs Office).

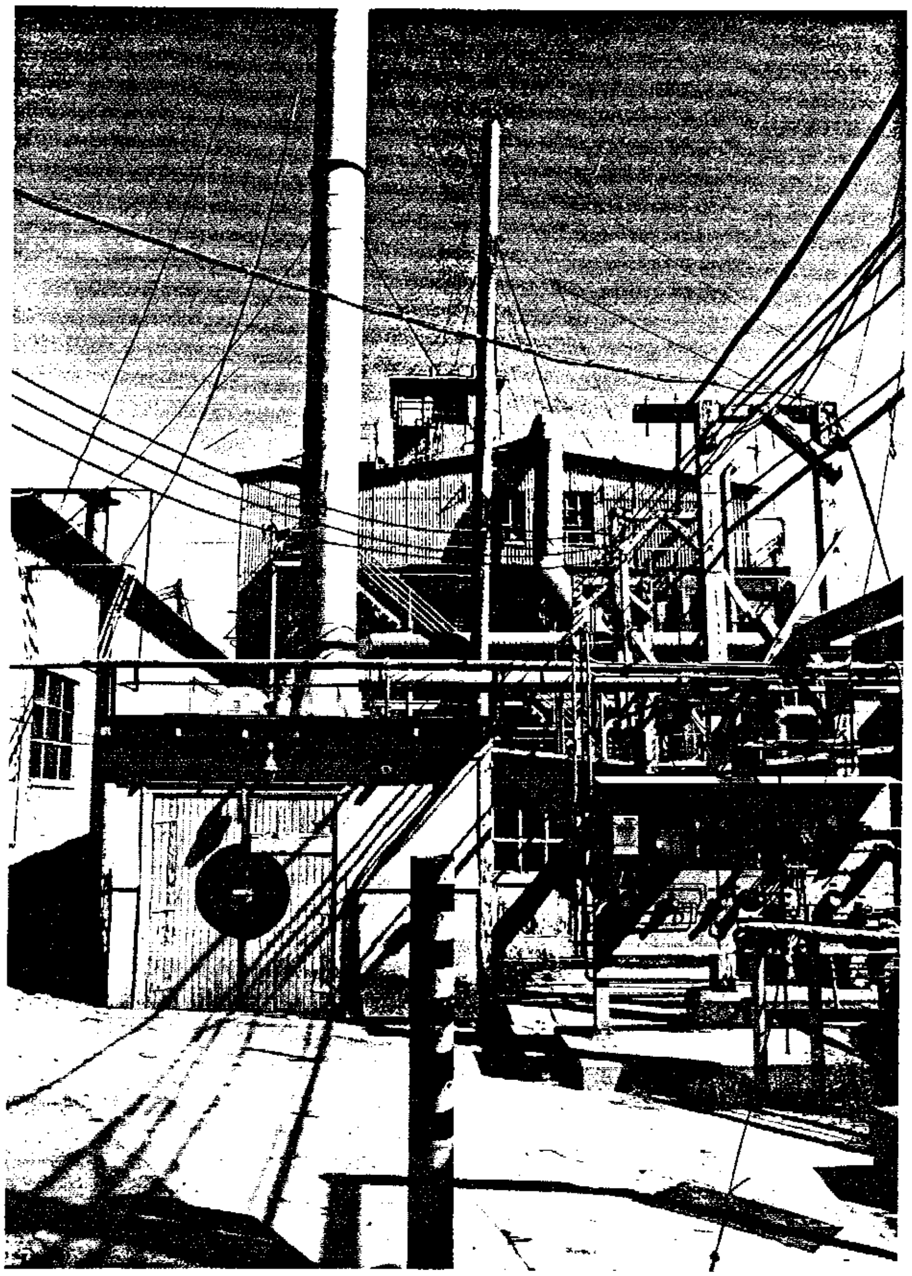

Figure 4: The former Lewisite Manufacturing Building (Building 514) is currently leased to Shell Oil Company (Source: Field inventory photograph, 1983, Jeffrey A. Hess, MacDonald and Mack Partnership).

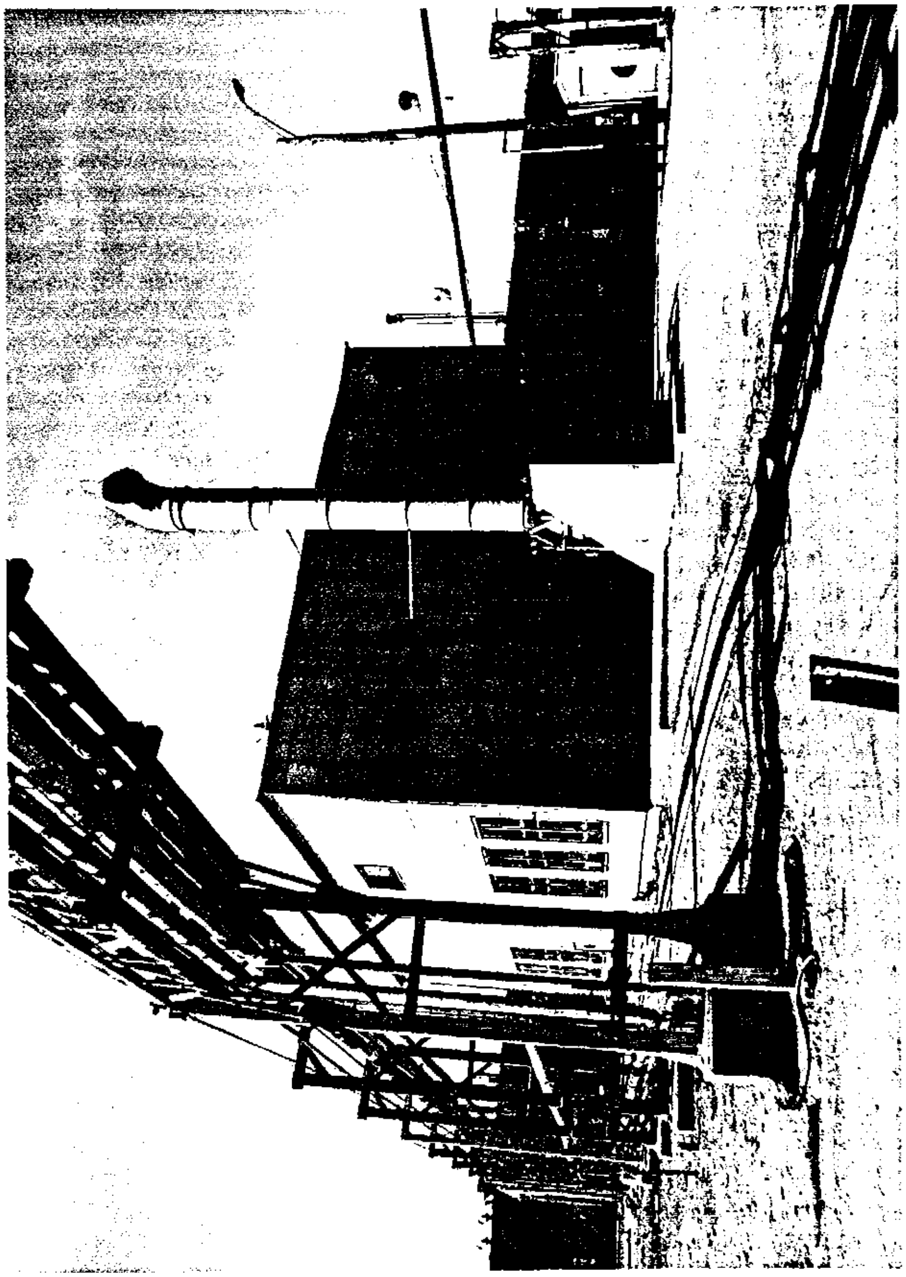

Figure 5: The former Mustard Gas Manufacturing Building (Building 422) is currently leased to Shell Oil Company (Source: Field inventory photograph, 1983, Jeffrey A. Hess, MacDonald and Mack Partnership).

Figure 6: The former Chlorine Manufacturing Building (Building 242) produced chlorine gas by the electrolysis of brine; it is now used as a warehouse (Source: "Rocky Mountain Arsenal Real Property Inventory," vol. 1, unpublished report prepared by Harland Bartholomew & Associates and Gilbert/Commonwealth Associates, Inc., 1982-1983).

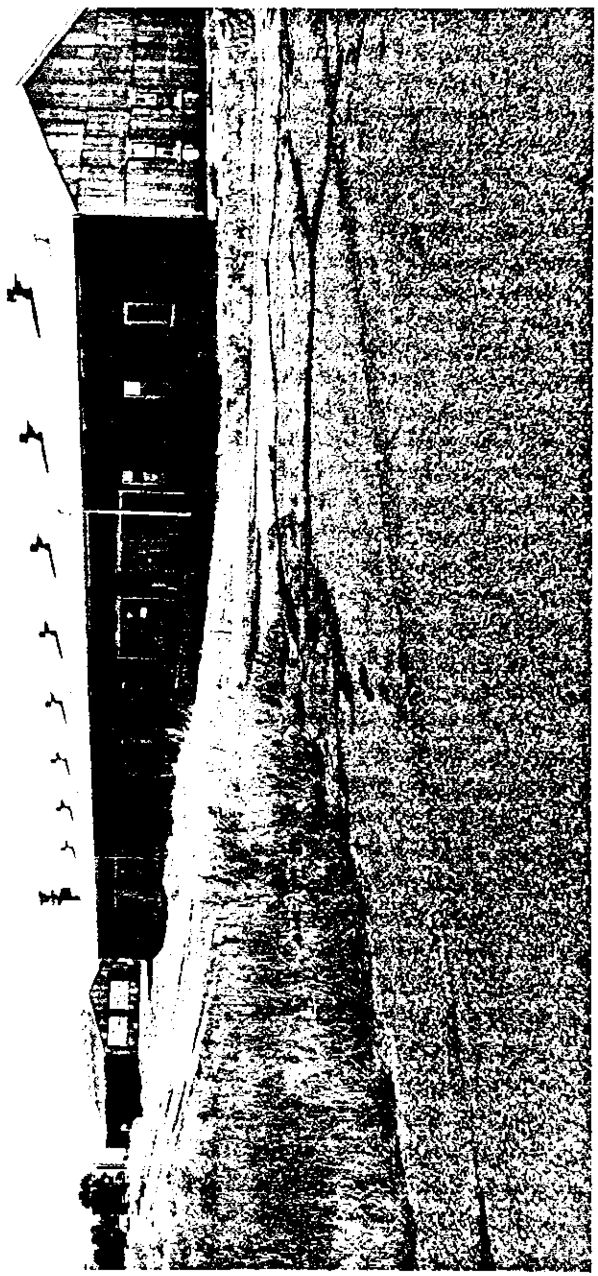

Figure 7: Building T-614 is typical of the warehouses in the arsenal's shop-and-storage area (Source: Field inventory photograph, 1983, Jeffrey A. Hess, MacDonald and Mack Partnership).

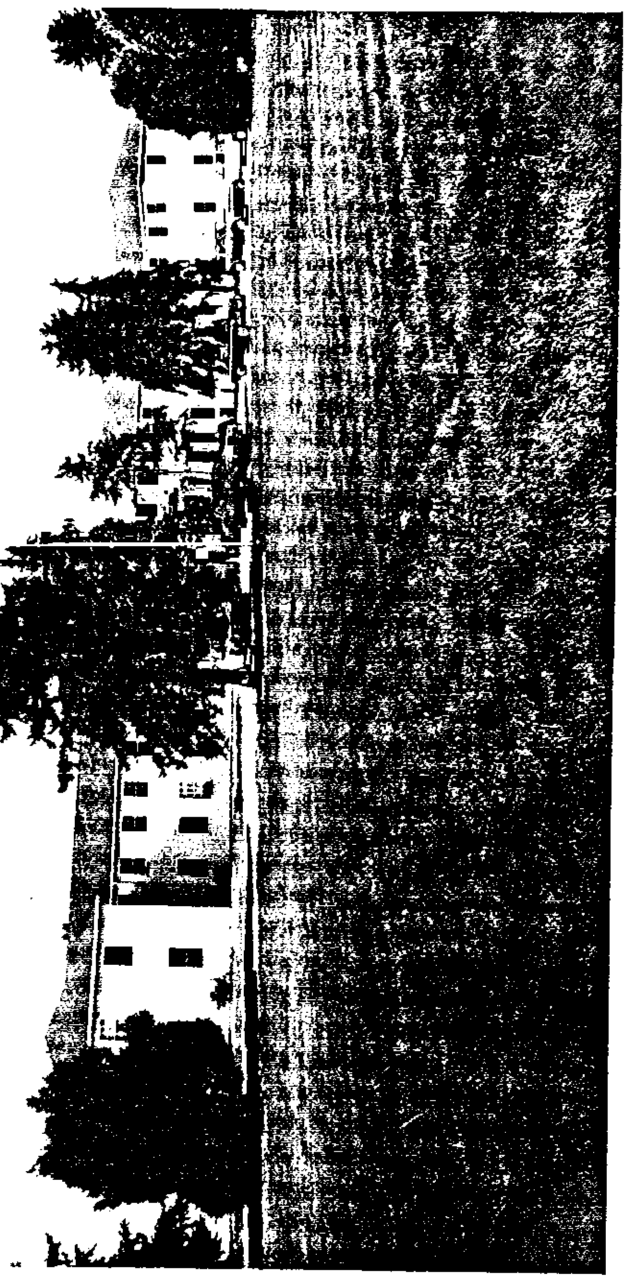

Figure 8: Administration Building (Building 111), looking north (Source: Field inventory photograph, 1983, Jeffrey A. Hess, MacDonald and Mack Partnership).

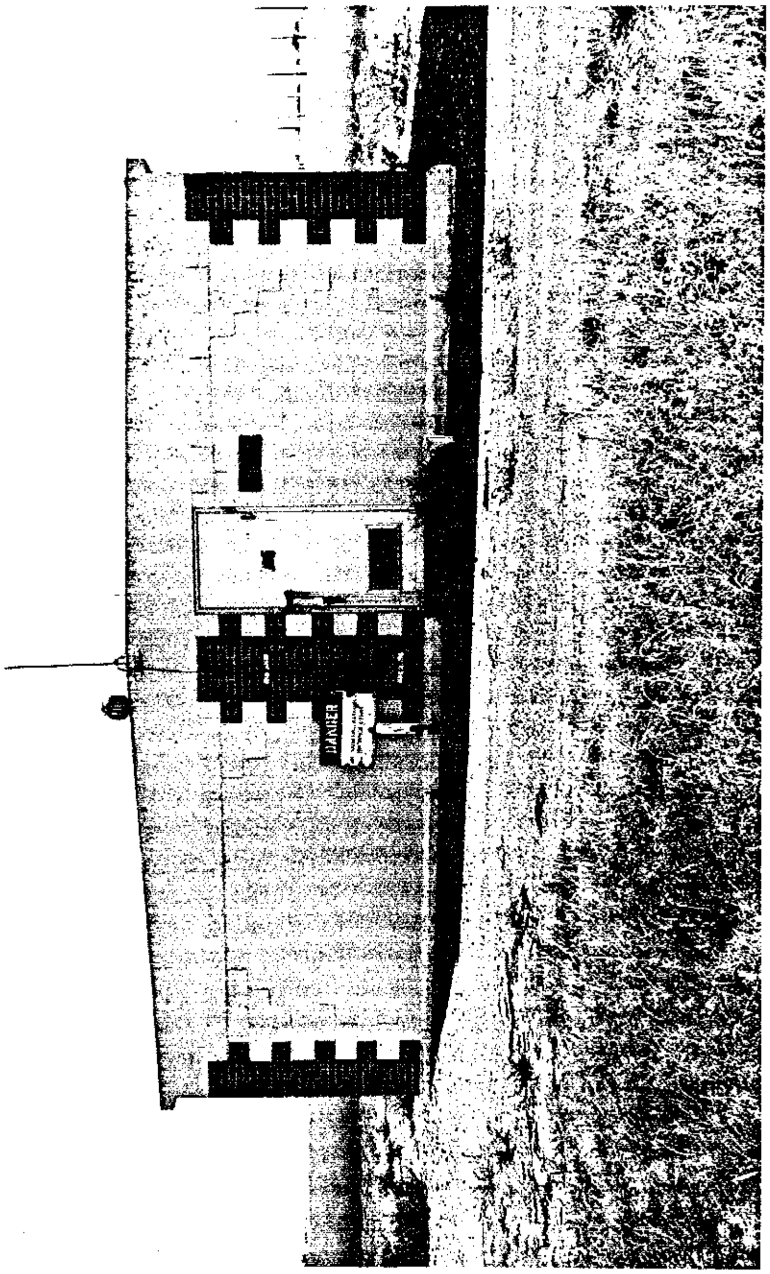


Figure 9: Building 871A is typical of the arsenal's above-ground storage magazines (Source: Field inventory photograph, 1983, Jeffrey A. Hess, MacDonald and Mack Partnership).

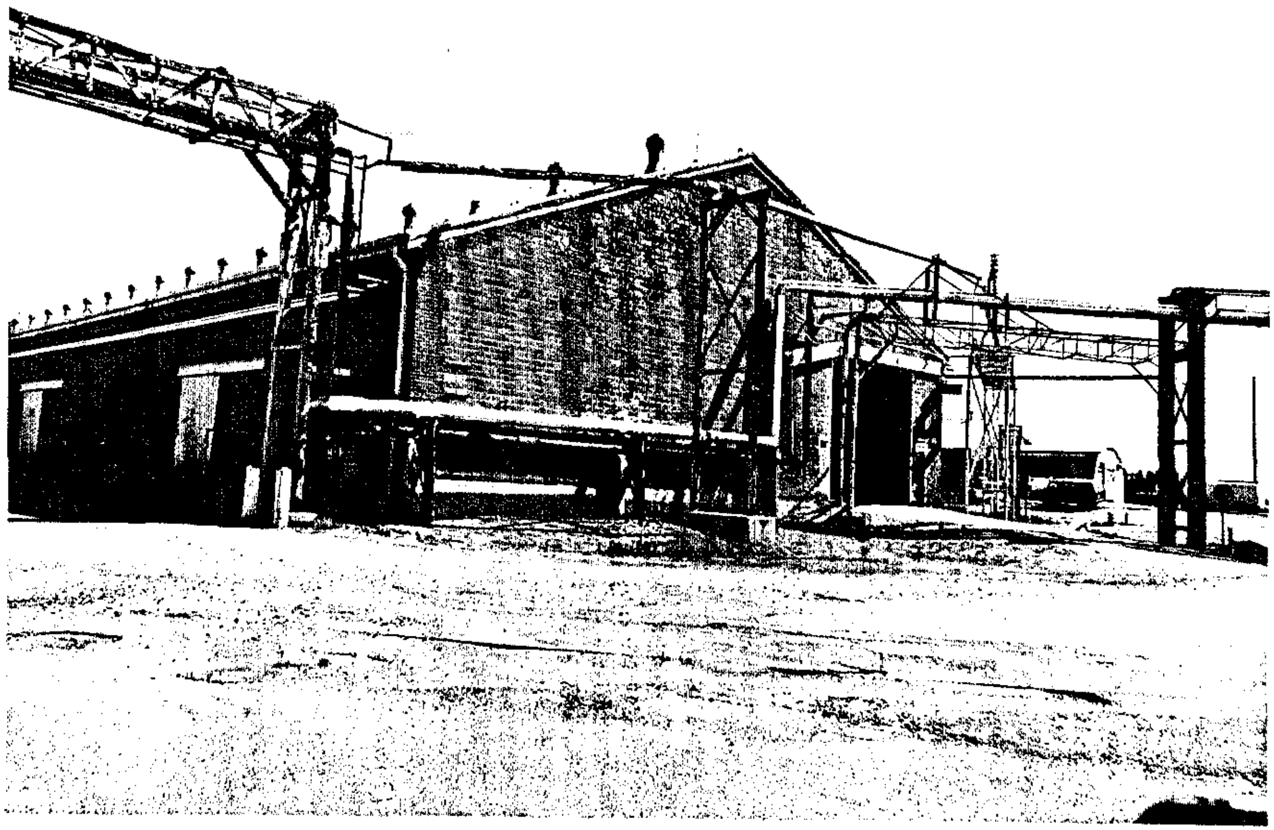

Figure 10: Building 742, formerly a napalm bomb filling plant, is currently a warehouse (Source: Field inventory photograph, 1983, Jeffrey A. Hess MacDonald and Mack Partnership).

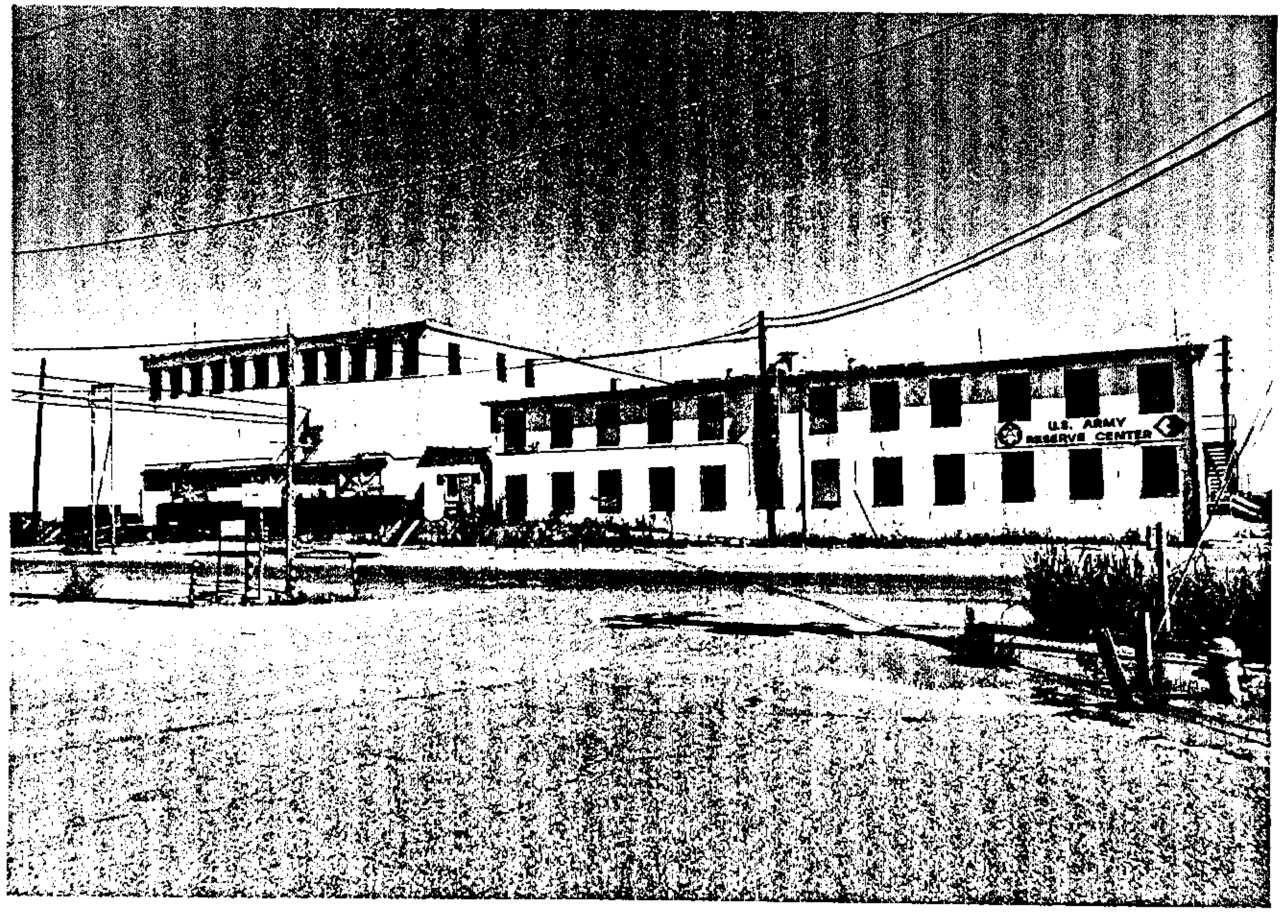


Figure 11: Originally designed as an incendiary bomb facility, Building 732 was not completed until after V-J Day. It currently provides office space for the Army Reserve (Source: Field inventory photograph, 1983, Jeffrey A. Hess, MacDonald and Mack Partnership).

Technology

By the end of World War II, RMA had experienced so many technological changes that, with the exception of the chlorine plant, the installation "was in one hundred percent production of items other than those for which it was originally designed."[7] Such widespread modification did not stem from any defect in planning. Rather, it resulted from the unpredictable nature of the war. When the Roosevelt Administration authorized the production of toxic gases during World War II, it was with the understanding that the United States "shall under no circumstances resort to the use of such weapons unless they are first used by our enemies."[8] In preparation for retaliatory strikes, the War Department stockpiled gas-filled munitions in all theaters of combat, but neither provocation nor retaliation ever occurred. Since gas-filled munitions were never expended, their supply quotas were quickly filled, resulting in manufacturing cutbacks at the chemical-warfare arsenals. At RMA, the mustard-manufacturing plant was deactivated and placed in standby condition as early as May 1943. The lewisite operation was shut down six months later and subsequently dismantled.

Both gas-manufacturing operations, along with the production processes for the various intermediate chemicals, employed standard industrial technologies. Mustard gas was made by the well-established Levinstein process, involving the reaction of ethylene gas and sulfur monochloride, with chlorine gas and caustic solution used for "neutralization and decontamination of spills, wild batches, and equipment." Lewisite was manufactured by a more recently developed English process that had been refined at Edgewood Arsenal. The procedure called for "the reaction between arsenic trichloride and gaseous acetylene in the presence of an aqueous hydrochloric acid solution of mercuric chloride [with] thionyl chloride . . . used for the completion of the reaction."[9] None of the arsenal's original production equipment for any of the chemical operations survives at the installation.

The suspension of war-gas production caused only a temporary lull at RMA. Almost immediately the Chemical Warfare Service began converting idle buildings to the manufacture of aerial incendiary munitions, which were in short supply in both Europe and the South Pacific. Between November 1943 and April 1945, several former warehouses (Buildings 451, 538, 541, 542) and chemical facilities (Buildings 522, 522A, 523, 523A, 523B) were adapted for the production of white-phosphorous cups and igniters, which formed part of the ignition train in incendiary bombs. Other buildings (Buildings 333, 341-346) were remodeled for napalm-loading and assembling of 10-pound bombs into 500-pound clusters. These activities augmented the RMA's original incendiary-munitions lines (Buildings 741, 742), which produced 100-pound napalm bombs.[10] Immediately following V-J Day, all incendiary manufacturing ceased, and RMA became a standby installation.

## KOREAN WAR

After the surrender of Japan, the federal government leased many of the RMA's former war-gas production buildings to private industry, with the understanding that all facilities would revert to military control in the event of a national emergency. The principal lessee was Julius Hyman and Company of Chicago, which used its new arsenal-based plant for the manufacture of insecticides and synthetic resins. In 1952 this operation was taken over by Shell Chemical Company, which had purchased the Chicago firm the previous year. Shell's leasehold at RMA has continued to the present time.[11]

RMA remained a standby installation until 1950, when the arsenal's incendiary-munitions lines were reactivated for the Korean War (Figure 12). At the same time, the government announced a $30 million construction program in the north-central section of the arsenal "for the manufacture of a top secret incendiary." Under the general supervision of the North Atlantic Division Engineers, Vitro Corporation served as architect, and Utah Construction Company as builder. After the project was completed in 1953, military officials revealed that the new facilities actually were for the production and loading of a highly toxic nerve agent originally developed by German scientists during World War II. The new substance was an organic phosphate compound, known as both Sarin and GB.[12] The RMA operation was designed to manufacture GB (Building 1501), load the nerve agent into projectiles, warheads, and bomblets (Building 1601), and assemble loaded bomblets into larger, cluster bombs (Building 1606) (Figure 13). Although nerve-agent loading operations continued throughout the 1960s (Figure 14), the GB Production Building (Building 1501) was shut down and placed in standby condition in 1957. Most of the nerve-agent manufacturing and loading machinery has been dismantled and removed from the arsenal.[13]

Figure 12: These arsenal employees who strapped together an incendiary-bomb cluster during the Korean War used the same labor-intensive assembly techniques as their World War II counterparts (Source: Denver Post, September 19, 1952).

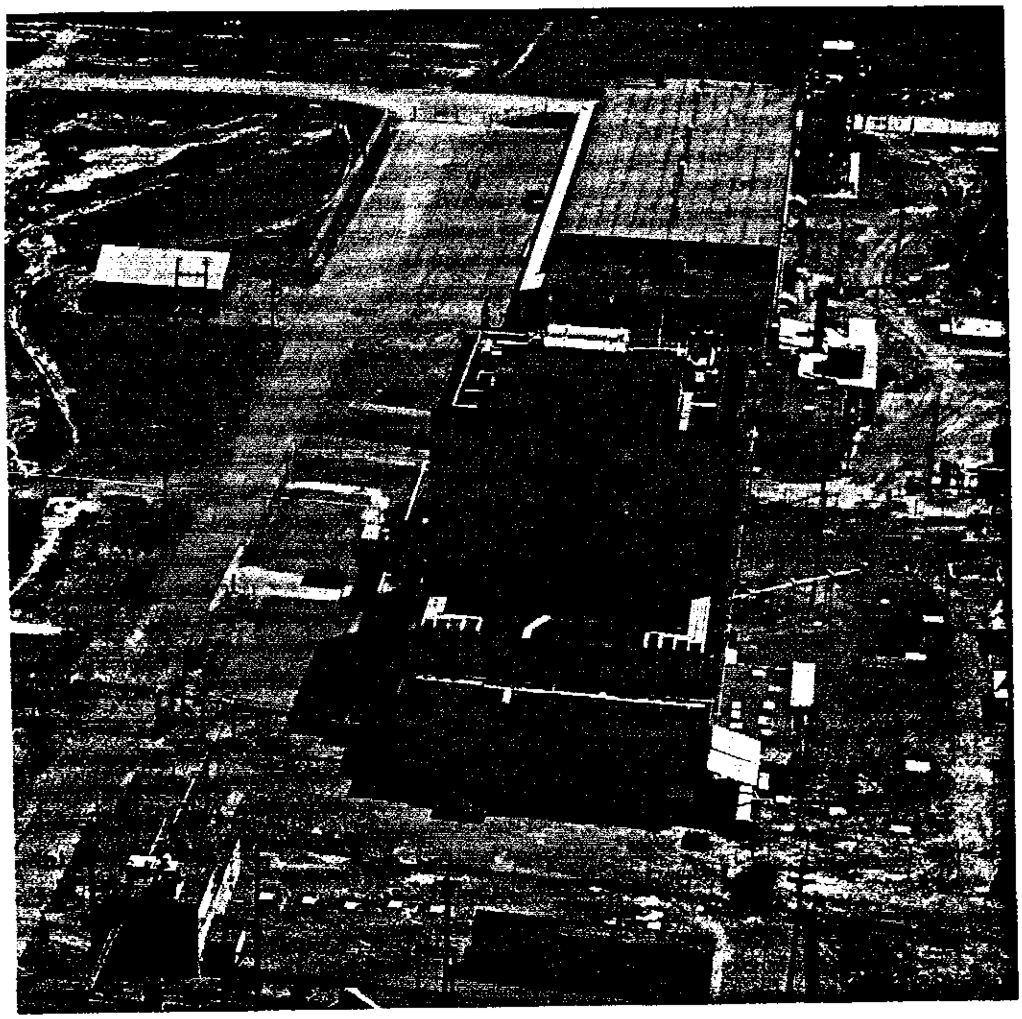

Figure 13: The production facility for nerve agent GB (Building 1501) is a seven-story reinforced-concrete structure currently in standby condition (Source: RMA Administrative Archives, c. 1980).

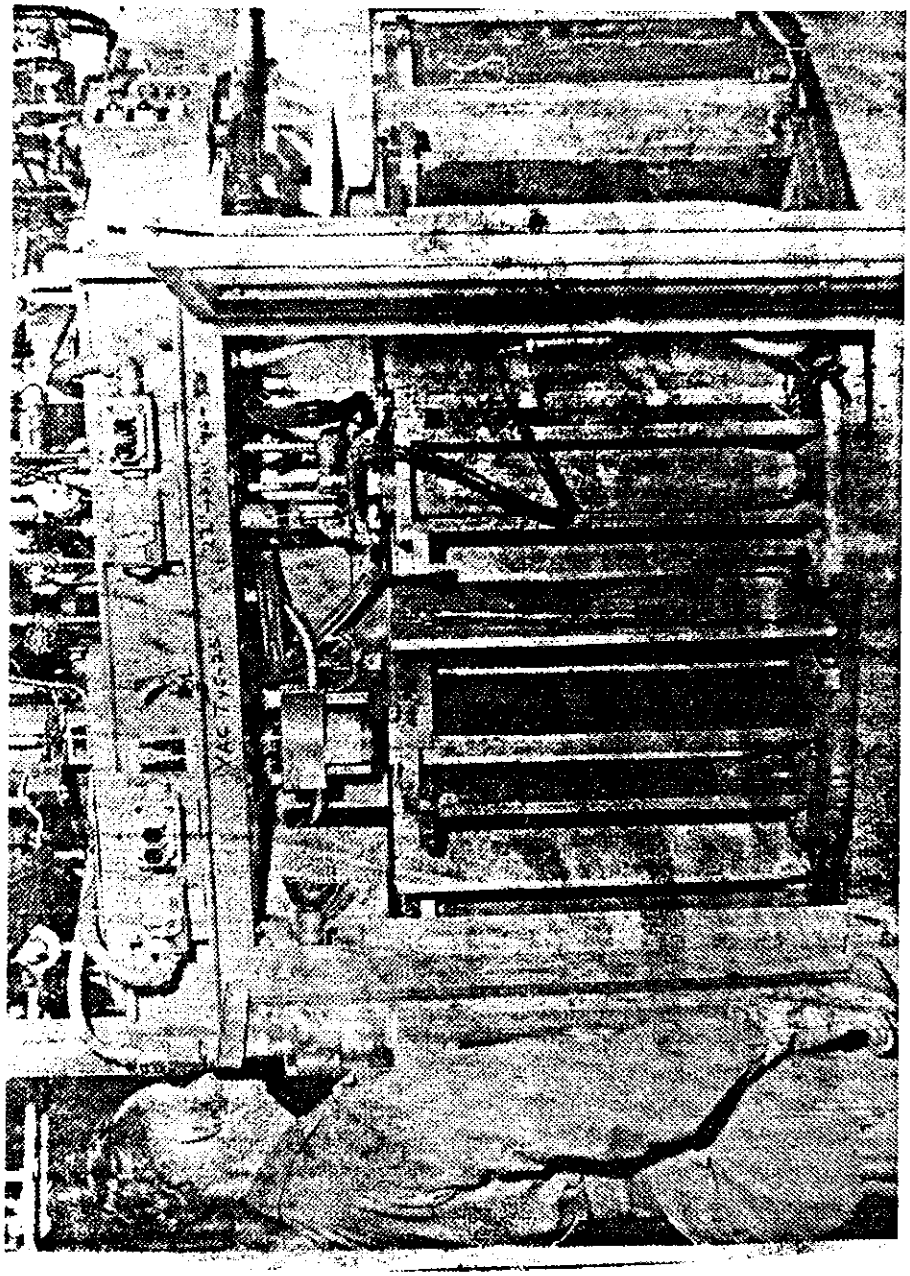

Figure 14: Automatic filling machine in Building 1601 loads nerve agent into rocket warhead in 1963 (Source: Denver Post, June 25, 1963).

## VIETNAM WAR TO THE PRESENT

After the resolution of the Korean War, RMA served as a research-and-development facility for chemical agents and munitions. Arsenal personnel, for example, developed improved methods for chemical-shell filling and engineered a facility for blending rocket fuels (Building 756). Although the arsenal reactivated its manufacturing lines for smoke and incendiary devices during the Vietnam War, the installation increasingly devoted its technological resources to the destruction rather than the production of chemical munitions.[14] In 1968 the Army decided that all excess and obsolete chemical stocks stored at RMA should be "demilitarized," or disposed of, by dumping at sea. This plan, called "Operation Chase," was scheduled to begin in April 1969, but public concern over safety and environmental issues led to its cancellation. In an attempt to find socially and environmentally acceptable alternatives, the Army submitted the problem to the National Academy of Sciences (NAS), which recommended the development of remote-control demilitarization techniques to "[minimize] the risk to all operating personnel as well as [to] the citizens of the surrounding communities."[15]

To comply with NAS recommendations, the Army designed and installed an innovative, nerve-gas detoxification system in the former GB Case-Filling Building (Building 1606). Demilitarization of GB cluster bombs began in the fall of 1973, and during the next three years approximately four million pounds of nerve agent were destroyed, representing "the largest single [demilitarization] undertaking in the history of the Army."[16] At the start of the operation, the local press provided the following description:

> The detoxification is done by remote control utilizing closed circuit television. The $33 million building in which the detoxification is conducted is under negative air pressure. That is air can enter the building, but no air can be released -- even if there's an explosion -- without passing through an elaborate scrubber system and an equally elaborate monitoring and alarm system that will shut the process down in the event of a malfunction. The detoxification system neutralizes the nerve gas with a caustic solution. Explosives in the bombs are burned away in a specially built furnace. The neutralized nerve gas agent is dried, and the solid residue is packed into 55-gallon drums for storage at the arsenal. The metal in the bombs also is neutralized and reduced to scrap.[17]

While the cluster-bomb disposal progam was in progress, the Army installed in Building 1606 a still more sophisticated detoxification center for the GB-filled Honest John Rocket and Weteye Bomb. Employing a completely computerized monitoring system and updated scrubbing towers, the system became operational for GB munitions in the spring of 1976. It has subsequently been used for disposing of a variety of obsolete toxic agents (Figure 15)[18].

Figure 15: In Building 1606 operators tend computer console that monitors dismantling and disposal of toxic munitions (Source: RMA Administrative Archives, c. 1977).

# NOTES

1. The standard study of American use of chemical munitions during World War II is Brooks E. Kleber and Dale Birdsell, The Chemical Warfare Service: Chemicals in Combat (Washington, D.C.: Office of the Chief of Military History, United States Army, 1966). On the role of Edgewood Arsenal and on the authorization of the three new installations, see Leo P. Brophy and George J. B. Fisher, The Chemical Warfare Service: Organizing for War (Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1959), pp. 10-13, 31-32, 36-37, 120-122.

2. Armed Service Forces, Chemical Warfare Service, "History of Rocky Mountain Arsenal," vol. 1, p. 4, unpublished report, 1945, RMA Administrative Archives.

3. "Army Chemical Plant Is Building in Denver," Denver Post, December 12, 1942. After World War II, approximately 2,500 acres of arsenal land were acquired by Stapleton International Airport, which borders the installation on the south. RMA's present size is 17,238 acres.

4. See section on "Engineering and Construction Contracts," in "History of Rocky Mountain Arsenal," Vol. 5, pp. 1270-1278. C. J. Kershaw Construction Company of Birmingham formed a joint venture with Swinerton and Walberg of San Francisco to build RMA. The contractors, as well as the architects, were assisted by H. A. Kuljian and Company of Philadelphia. Whitman, Requart and Smith designed all of the industrial structures, except for the chlorine plant and the thionyl chloride plant, which were the work of H. K. Ferguson Company of Cleveland. E. I du Pont de Nemours & Co. served as design consultant for Whitman, Requart and Smith; Hooker Electro-Chemical Company played a similar role for H. K. Ferguson Company.

5. On the unique layout of RMA, see "History of Rocky Mountain Arsenal, vol. 2, pp. 431-432.

6. See "History of Rocky Mountain Arsenal," vol. 1, pp. 46-55; vol. 2, p. 578; vol. 4, pp. 1124-1127; vol. 5, pp. 1275-1277; vol 9, p. 2965.

7. "History of Rocky Mountain Arsenal," vol. 1, p. 20.

8. Roosevelt's statement on gas warfare is quoted in Brophy and Fisher, p. 88. The stockpiling of gas munitions in combat areas is discussed in Kleber and Birdsell, pp. 36-276.

9. "History of Rocky Mountain Arsenal," vol. 8, pp. 2510, 2592.

10. The various incendiary-manufacturing operations are described in "History of Rocky Mountain Arsenal," vol. 2, pp. 437-457, 473-476; vol. 3, pp. 879-884, 905; vol. 4, pp. 1074-1101, 112-1130, 1164-1170.

11. On leasehold arrangements, see Denver Post, January 13, 1947, November 29, 1951, March 20, 1964; "History of Rocky Mountain Arsenal," unpublished report, 1980, p. 3.

12. On the construction of the GB plant, see Cal Queal, "The Many Secrets of Rocky Mountain Arsenal," Denver Post--Empire Magazine, April 13, 1969, 11; also, "History of Installation/Activity," unpublished report, c. 1980, p. 1, RMA Administrative Archives. Historical background on the development of GB is found in "Nerve Gases Unveiled," Chemical and Engineering News, 31 (November 9, 1953), 4676-4677.

13. Author's interview with Dr. William McNeill, RMA Director of Technical Operations, September 1983. Inventories of surviving GB production equipment are listed under appropriate building number in "Rocky Mountain Arsenal Real Property Inventory," 7 vols., unpublished report prepared by Harland Bartholomew & Associates and Gilbert/Commonwealth, 1982-1983, RMA Facilities Engineer's Office Archives.

14. "History of Rocky Mountain Arsenal," 1980, p. 5.

15. "History of Rocky Mountain Arsenal," 1980, p. 6.

16. "History of Rocky Mountain Arsenal," 1980, p. 7.

17. Tom Rees, "Nerve Gas Detoxification Begins at Arsenal," Rocky Mountain News, October 30, 1973.

18. "History of Rocky Mountain Arsenal," 1980, p. 9; "Rocky Mountain Arsenal Chemical Demilitarization Facilities and Equipment," unpublished report, c. 1980, RMA Administrative Archives.

# Chapter 3

# PRESERVATION RECOMMENDATIONS

## BACKGROUND

Army Regulation 420-40 requires that an historic preservation plan be developed as an integral part of each installation's planning and long-range maintenance and development scheduling.[1] The purpose of such a program is to:

- Preserve historic properties to reflect the Army's role in history and its continuing concern for the protection of the nation's heritage.
- Implement historic preservation projects as an integral part of the installation's maintenance and construction programs.
- Find adaptive uses for historic properties in order to maintain them as actively used facilities on the installation.
- Eliminate damage or destruction due to improper maintenance, repair, or use that may alter or destroy the significant elements of any property.
- Enhance the most historically significant areas of the installation through appropriate landscaping and conservation.

To meet these overall preservation objectives, the general preservation recommendations set forth below have been developed:

### Category I Historic Properties

All Category I historic properties not currently listed on or nominated to the National Register of Historic Places are assumed to be eligible for nomination regardless of age. The following general preservation recommendations apply to these properties:

a) Each Category I historic property should be treated as if it were on the National Register, whether listed or not. Properties not currently listed should be nominated. Category I historic properties should not be altered or demolished. All work on such properties shall be performed in accordance with Sections 106 and 110(f) of the National Historic Preservation Act as amended in 1980, and the regulations of the Advisory Council for Historic Preservation (ACHP) as outlined in the "Protection of Historic and Cultural Properties" (36 CFR 800).

b) An individual preservation plan should be developed and put into effect for each Category I historic property. This plan should delineate the appropriate restoration or preservation program to be carried out for the property. It should include a maintenance and repair schedule and estimated initial and annual costs. The preservation plan should be approved by the State Historic Preservation Officer and the Advisory Council in accordance with the above-referenced ACHP regulation. Until the historic preservation plan is put into effect, Category I historic properties should be maintained in accordance with the recommended approaches of the Secretary of Interior's Standards for Rehabilitation and

Revised Guidelines for Rehabilitating Historic Buildings[2] and in consultation with the State Historic Preservation Officer.

c) Each Category I historic property should be documented in accordance with Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER) Documentation Level II, and the documentation submitted for inclusion in the HABS/HAER collections in the Library of Congress.[3] When no adequate architectural drawings exist for a Category I historic property, it should be documented in accordance with Documentation Level I of these standards. In cases where standard measured drawings are unable to record significant features of a property or technological process, interpretive drawings also should be prepared.

Category II Historic Properties

All Category II historic properties not currently listed on or nominated to the National Register of Historic Places are assumed to be eligible for nomination regardless of age. The following general preservation recommendations apply to these properties:

a) Each Category II historic property should be treated as if it were on the National Register, whether listed or not. Properties not currently listed should be nominated. Category II historic properties should not be altered or demolished. All work on such properties shall be performed in accordance with Sections 106 and 110(f) of the National Historic Preservation Act as amended in 1980, and the regulations of the Advisory Council for Historic Preservation (ACHP) as outlined in the "Protection of Historic and Cultural Properties" (36 CFR 800).

b) An individual preservation plan should be developed and put into effect for each Category II historic property. This plan should delineate the appropriate preservation or rehabilitation program to be carried out for the property or for those parts of the property which contribute to its historical, architectural, or technological importance. It should include a maintenance and repair schedule and estimated initial and annual costs. The preservation plan should be approved by the State Historic Preservation Officer and the Advisory Council in accordance with the above-referenced ACHP regulations. Until the historic preservation plan is put into effect, Category II historic properties should be maintained in accordance with the recommended approaches in the Secretary of the Interior's Standards for Rehabilitation and Revised Guidelines for Rehabilitating Historic Buildings[4] and in consultation with the State Historic Preservation Officer.

c) Each Category II historic property should be documented in accordance with Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER) Documentation Level

II, and the documentation submitted for inclusion in the HABS/HAER collections in the Library of Congress.[5]

Category III Historic Properties

The following preservation recommendations apply to Category III historic properties:

a) Category III historic properties listed on or eligible for nomination to the National Register as part of a district or thematic group should be treated in accordance with Sections 106 and 110(f) of the National Historic Preservation Act as amended in 1980, and the regulations of the Advisory Council for Historic Preservation as outlined in the "Protection of Historic and Cultural Properties" (36 CFR 800). Such properties should not be demolished and their facades, or those parts of the property that contribute to the historical landscape, should be protected from major modifications. Preservation plans should be developed for groupings of Category III historic properties within a district or thematic group. The scope of these plans should be limited to those parts of each property that contribute to the district or group's importance. Until such plans are put into effect, these properties should be maintained in accordance with the recommended approaches in the Secretary of the Interior's Standards for Rehabilitation and Revised

Guidelines for Rehabilitating Historic Buildings[6] and in consultation with the State Historic Preservation Officer.

b) Category III historic properties not listed on or eligible for nomination to the National Register as part of a district or thematic group should receive routine maintenance. Such properties should not be demolished, and their facades, or those parts of the property that contribute to the historical landscape, should be protected from modification. If the properties are unoccupied, they should, as a minimum, be maintained in stable condition and prevented from deteriorating.

HABS/HAER Documentation Level IV has been completed for all Category III historic properties, and no additional documentation is required as long as they are not endangered. Category III historic properties that are endangered for operational or other reasons should be documented in accordance with HABS/HAER Documentation Level III, and submitted for inclusion in the HABS/HAER collections in the Library of Congress.[7] Similar structures need only be documented once.

## CATEGORY I HISTORIC PROPERTIES

There are no Category I historic properties at the RMA.

## CATEGORY II HISTORIC PROPERTIES

There are no Category II historic properties at the RMA.

## CATEGORY III HISTORIC PROPERTIES

There are no Category III historic properties at the RMA.

## NOTES

1. Army Regulation 420-40, Historic Preservation (Headquarters, U.S. Army: Washington, D.C., 15 April 1984).

2. National Park Service, Secretary of Interior's Standards for Rehabilitation and Revised Guidelines for Rehabilitating Historic Buildings, 1983 (Washington, D.C.: Preservation Assistance Division, National Park Service, 1983).

3. National Park Service, "Archeology and Historic Preservation; Secretary of the Interior's Standards and Guidelines," Federal Register, Part IV, 28 September 1983, pp. 44730-44734.

4. National Park Service, Secretary of the Interior's Standards.

5. National Park Service, "Archeology and Historic Preservation."

6. National Park Service, Secretary of the Interior's Standards.

7. National Park Service, "Archeology and Historic Preservation."

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Historic American Buildings Survey/Historic American Engineering Record, National Park Service. Guidelines for Inventories of Historic Buildings and Engineering and Industrial Structures. Unpublished draft, 1982.

"History of Installation/Activity." Unpublished report, c. 1980. RMA Administrative Archives. Historical sketch of RMA.

"History of Rocky Mountain Arsenal." Unpublished report, 1980. RMA Administrative Archives. Particularly good discussion of detoxification activities of the 1970s.

Hoy, Suellen M., and Robinson, Michael C., eds. Public Works History in the United States. Nashville: American Association for State and Local History, 1982.

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Kleber, Brooks E., and Birdsell, Dale. The Chemical Warfare Service: Chemicals in Combat. Wash., D.C.: Office of the Chief of Military History, United States Army, 1966. Standard study of American development and deployment of chemical munitions during World War II.

National Park Service. "Archeology and Historic Preservation; Secretary of the Interior's Standards and Guidelines." Federal Register, Part IV (September 28, 1983), 44730-44734.

________________. How to Complete National Register Forms. Washington, D. C.: U. S. Government Printing Office, 1977.

______________. Secretary of Interior's Standards for Rehabilitation and Revised Guidelines for Rehabilitating Historic Buildings, 1983. Washington, D. C.: Preservation Assistance Division, National Park Service, 1983.

"Nerve Gases Unveiled." Chemical and Engineering News, 31 (November 9, 1953), 4676-4677. Brief note on the chemistry and discovery of nerve agent GB and related compounds.

Queal, Cal. "The Many Secrets of Rocky Mountain Arsenal." Denver Post--Empire Magazine. April 13, 1969.

Rees, Tom. "Nerve Gas Detoxification Begins at Arsenal." Rocky Mountain News. Oct. 30, 1973.

"Rocky Mountain Arsenal Chemical Demilitarization Facilities and Equipment." Unpublished report, c. 1980. RMA Administrative Archives. Excellent technical description of RMA detoxification program.

"Rocky Mountain Arsenal General Site Plan." Unpublished drawing X2-1-33. November 29, 1973; rev. June 9, 1981. RMA Facilities Engineer's Office Archives.

Rocky Mountain Arsenal Real Property Inventory. Unpublished computer printout, March 1982. RMA Facilities Engineer's Office Archives.

"Rocky Mountain Arsenal Real Property Inventory." Unpublished report prepared by Harland Bartholomew & Associates and Gilbert/Commonwealth, 1982-1983. 7 vols. RMA Facilities Engineer's Office Archives. Condition survey of existing facilities at RMA.

United States Army Armament Materiel Readiness Command. Catalog of Common Sources, Fiscal Year 1983. No pl.: Historical Office, AMCCOM, Rock Island Arsenal, n.d. 2 vols.

ADDENDUM TO

HAER No. CO-21

HAER
COLO
1-COMCI,
1-

Rocky Mountain Arsenal
Bounded by 96th and 56th Avenues,
Buckley Road, Quebec Street, and
Colorado Highway 2
Commerce City
Adams County
Colorado

PHOTOGRAPHS

HISTORICAL AND DESCRIPTIVE DATA

REDUCED MEASURED DRAWINGS

HISTORIC AMERICAN ENGINEERING RECORD
Rocky Mountain Regional Office
National Park Service
P.O. Box 25287
Denver, Colorado 80225-0287

# HISTORIC AMERICAN ENGINEERING RECORD

## ROCKY MOUNTAIN ARSENAL

This report is an addendum to a fifty-one page report previously transmitted to the Library of Congress.

Location: Bounded by 96th and 56th Avenues, Buckley Road, Quebec Street and Colorado Highway 2, Commerce City, Adams County, Colorado

Date of Construction: 1942

Fabricator: Army Corps of Engineers; Whitman, Requardt, and Smith; H.A. Kuljian and Company; H.K. Ferguson Company; Kershaw, Heyer, Swinerton, and Walberg; E.I. DuPont de Nemours and Company; Shell Chemical Company

Present Owner: U.S. Department of the Army

Present Use: Inactive chemical weapons production plant, presently undergoing cleanup as a Superfund site under the Comprehensive Environmental Response, Compensation and Liability Act; also designated by Congress as a national wildlife refuge, and is a important habitat for wildlife, including bald eagles.

Significance: Rocky Mountain Arsenal is internationally significant for its role in chemical weapons technology, particularly as the only manufacturing facility for the nerve agent Sarin outside of the former Soviet Union. But Rocky Mountain Arsenal is nationally significant, as well, because of the decades-long controversy over contamination that has influenced the discussion of hazardous materials and their impact on communities well beyond the region, the designation as a Superfund site under the Comprehensive Environmental Response, Compensation and Liability Act, and the innovative technology developed there in response to unique cleanup problems.

Historian: Michael G. Schene, Ph.D., January 1997

NOTE: **All of the documents, reports, secondary materials, and interviews cited in the footnotes and bibliography contain only nnclassified materials. Further, all of the descriptions of the chemical manufacturing processes have been extensively reviewed by military personnel for security purposes.**

Project Information:

Rocky Mountain Arsenal was declared eligible for listing on the National Register of Historic Places through a Determination of Eligibility agreed to by the Department of the Army (Army) and the Colorado State Historic Preservation Officer (CSHPO) on August 19, 1993. Prior to completing cleanup, the Army initiated consultation pursuant to Section 106 of the National Historic Preservation Act of 1966, amended. As a result of this consultation, an "Interim Memorandum of Agreement" was signed between the Army, the CSHPO, and the Advisory Council on Historic Preservation on December 3, 1993. One of the stipulations of this Interim Memorandum of Agreement provided that the Army would document the site according to the standards of the Historic American Engineering Record (HAER) and place the documentation in the Library of Congress. The Army requested that the U.S. Department of the Interior, National Park Service (NPS), Intermountain Field Area Office, Rocky Mountain System Support Office, complete this documentation for them. An Interagency Agreement was signed between the NPS and the Army on July 12, 1994. The work was divided into three components: history,
large-format photographs, and architectural drawings, both historic and contemporary. The
large-format photographs and architectural drawings were completed under contract by FrasierDesign, Loveland, Colorado; the history was completed by NPS Historian Dr. Michael G. Schene. Mr. Gregory Kendrick, Program Leader, Cultural Resources, Rocky Mountain System Support Office, NPS supervised and managed the project; Colonel Eugene Bishop was the Program Manager at Rocky Mountain Arsenal, Army.

As a separate component, the NPS will use the HAER documentation to produce "an illustrated history of the industrial facilities,including a book-length readable publication as well as a smaller interpretive brochure."

| STRUCTURE NAME | STRUCTURE # | HAER No. |
|---|---|---|
| Vehicle Maintenance Shop | Bldg. 317 | 21-A |
| Mustard Manufacturing/Filling Building | Bldg. 412 | 21-B |
| Ethylene Dryer/Compressor, Refrigeration Bldg. | Bldg. 431 | 21-C |
| Ethylene Generator/R&D Lab | Bldg. 433 | 21-D |
| Arsenic Trioxide Dry Storage Silo | Bldg. 523G | 21-E |
| Laundry Facility Tank (Wastewater) | Tank NNT0108 | 21-F |
| Storage Tank (Standby Fuel Oil) | Tank 0321B | 21-G |
| Goop Mixing and Filling Tank (Near Bldg. 328) | Tank T0007 | 21-H |
| Tank (Manufacturing NaOH Makeup) | Tank T0032 | 21-I |
| West Gas.Holder (Ethlene gas in Mustard Production) | Tank T0434 | 21-J |
| East Gas Holder (Ethlene gas in Mustard Production) | Tank T0435 | 21-K |
| Storage Tank (Fuel Oil) | Tank 0462A | 21-L |
| Storage Tank (Alcohol Storage for Mustard Produc.) | Tank 0463F | 21-M |
| Gasoline Storage Tank | Tank 0745C | 21-N |
| Flare Tower | Tank T-1024 | 21-O |
| Storage Tank (Acetone for Planavin Production) | Tank T0014 | 21-P |
| Storage Tank (Acetone for Planavin Production) | Tank T0160 | 21-Q |
| Storage Tank (Chlorinated Parrafin Production) | Tank T0164 | 21-R |
| Storage Tank (Hexachlorpentadiene) | Tank T0065 | 21-S |
| Storage tank (DCPD/BCH) | Tank T0075 | 21-T |
| Storage Tank (Hazardous Substance) | Tank T0197 | 21-U |
| Storage Tank (Azodrin Production) | Tank T1151 | 21-V |
| Storage Tank (Pesticide Production) | Tank T0058 | 21-W |
| Storage Tank (Methol Alcohol, Acetone) | Tank T1027 | 21-X |
| Storage Tank (Aldrin) | Tank T1134 | 21-Y |
| Storage Vessel (Vinyl Chloride for Endrin Produc.) | Tank V1001 | 21-Z |
| Boiler Plant/Central Gas Heat Plant | Bldg.321 | 21-AA |
| Electrical Power Plant | Bldg. 325 | 21-AB |
| Sulfur Monochloride and Sulfur Dichloride Mfg. | Bldg. 411 | 21-AC |
| Steam Flow Metering Facility | Bldg. 411B | 21-AD |
| Refrigeration; Napalm and Incendiary Bomb Warehouse; Bomb Filling | Bldg. 741/742 | 21-AE |
| Tank House (Distilled Mustard) | Bldg. 742-A | 21-AF |
| Crude Mustard (H) and Aldrin Manufacturing | Bldg. 422 | 21-AG |
| Administration/Lab/Change House | Bldg. 241 | 21-AH |
| Bomb Rack | | 21-AI |
| Chlorine Production Cell Building | Bldg. 242/243 | 21-AJ |
| FIRE STATION | Bldg. 312 | 21-AK |

AN



| STRUCTURE NAME | STRUCTURE # | HAER No. |
|---|---|---|
| | Bldg. 111 | 21-AL |
| Communication Building | Bldg. 112 | 21-AM |
| Cafeteria/office/Storage Building | Bldg. 311 | 21-AN |
| Laboratory Building | Bldg.313 | 21-AO |
| Laundry Service Building | Bldg. 314 | 21-AP |
| Laundry Warehouse | Bldg. 315 | 21-AQ |
| Fuel Storage Silo | Bldg. 323 | 21-AR |
| Goop Mixing and Filling Building | Bldg. 328 | 21-AS |
| Gasoline Pump Building | Bldg. 329 | 21-AT |
| Phosgene Filling and Storage Building | Bldg. 331 | 21-AU |
| Locker Room/Change House | Bldg. 337 | 21-AV |
| Chlorine Evaporator and Storage Building | Bldg. 251 | 21-AW |
| Caustic Fusion Building | Bldg. 254 | 21-AX |
| Storage Warehouse for Incendiary Clusters | Bldg. 346 | 21-AY |
| Storage Warehouse | Bldg. 356 | 21-AZ |
| Storage Warehouse | Bldg. 362 | 21-BA |
| Explosives Blending Building | Bldg. 365 | 21-BB |
| Water Tower | | 21-BC |
| Mustard Brine Mixing Building | Bldg. 429 | 21-BD |
| Production Filling and Storage Building | Bldg. 451 | 21-BE |
| Acetylene Generator Building | Bldg. 452 | 21-BF |
| Thionyl Chloride Reaction/Drum Loading Building | Bldg. 471/473 | 21-BG |
| Thionyl Chloride Refrigeration Building | Bldg. 472 | 21-BH |
| Thionyl Chloride Railroad Car Warming Shed | Bldg. 475 | 21-BI |
| Crude Mustard Distillation Building | Bldg. 515 | 21-BJ |
| Chlorinated Paraffin Manufacturing Building | Bldg. 511 | 21-BK |
| Lewisite Filling and Distilled Mustard Filling Building | Bldg. 512 | 21-BL |
| Lewisite Reactor & Distilled Mustard Distillation Plant | Bldg. 514 | 21-BM |
| Lewisite/Distilled Mustard Manufacturing Building | Bldg. 516 | 21-BN |
| Lewisite and Distilled Mustard Change House/Lab | Bldg. 517 | 21-BO |
| Acetylene Compressor House | Bldg. 521 | 21-BP |
| Acetylene Scrubbing Building/Product Development Laboratory | Bldg. 525 | 21-BQ |
| Distilled Mustard Residue Burner | Bldg. 528 | 21-BR |
| Storage Warehouse | Bldg. 531 | 21-BS |
| Pesticide Filling and Storage Building | Bldg. 532 | 21-BT |
| Thaw House/Distilled Mustard Drum Disposal | Bldg. 538 | 21-BU |
| White Phosphorous Filling/Acetylene Building | Bldg. 541 | 21-BV |
| White Phosphorous Filling/Acetylene Generation Building, Warehouse | Bldg. 522 | 21-BW |

| STRUCTURE NAME | STRUCTURE # | HAER No. |
|---|---|---|
| Maintenance Shop | Bldg. 543 | 21-BX |
| Acetylene Gas Holder Building | Bldg. 519 | 21-BY |
| Pesticide Incinerator/Precipitator | Bldg. 724 | 21-BZ |
| Facilities Maintenance Building | Bldg. 727 | 21-CA |
| Mustard Filling and Storage Building | Bldg. 728 | 21-CB |
| Storage Warehouse | Bldg. 729 | 21-CC |
| Army Reserve Center | Bldg. 731/732 | 21-CD |
| Process Control Building | Bldg. 735 | 21-CE |
| Valve/Pump House | Bldg. 744 | 21-CF |
| Control Building/Paint Storage Warehouse | Bldg. 748 | 21-CG |
| Paint and Process Shop/Surveillance Magazine | Bldg. 751 | 21-CH |
| Carpentry Shop/Surveillance Magazine | Bldg. 752 | 21-CI |
| Property Office | Bldg. 611 | 21-CJ |
| Courier Building | Bldg. 612 | 21-CK |
| Fire House | Bldg. 613 | 21-CL |
| Warehouse | Bldg. 616 | 21-CM |
| Storage Warehouse | Bldg. 618 | 21-CN |
| Warehouse | Bldg. 619 | 21-CO |
| Salvage/Surplus Facility | Bldg. 621 | 21-CP |
| Paint Shop | Bldg. 622 | 21-CQ |
| Carpenter Shop/Hobby Shop/Auto Shop | Bldg. 623 | 21-CR |
| Machine Shop | Bldg. 624 | 21-CS |
| Warehouse | Bldg. 625 | 21-CT |
| Vehicle Maintenance Shop | Bldg. 627 | 21-CU |
| Service Station | Bldg. 629 | 21-CV |
| Heating Plant | Bldg. 632 | 21-CW |
| General Instruction Building | Bldg. 633 | 21-CX |
| Motor Pool | Bldg. 647 | 21-CY |
| Railside Filling Area | | 21-CZ |
| General Instruction Building | Bldg. 1705 | 21-DA |
| Sarin Manufacturing Building | Bldg. 1501 | 21-DB |
| Scrubber Building | Bldg. 1503 | 21-DC |
| Sarin Storage Building | Bldg. 1506 | 21-DD |
| Cluster Bomb Assembly/Filling/Storage Building | Bldg. 1601/06 | 21-DE |
| Hospital Clinic and Administration Building | Bldg. 1710 | 21-DF |
| Ammunition Demolition Building | Bldg. 1703 | 21-DG |
| Cooling Tower | Bldg. 1707 | 21-DH |
| Ammunition Demolition Building/Tail Fin Storage and Assembly | Bldg. 1611 | 21-DI |
| Ammunition Demolition Building/Paint Storage | Bldg. 1602 | 21-DJ |

| STRUCTURE NAME | STRUCTURE # | HAER No. |
|---|---|---|
| Storage Building/Explosive Unpacking | Bldg. 1613 | 21-DK |
| Compressed Air Plant | Bldg. 1704 | 21-DL |
| Sentry Station | Bldg. 1706 | 21-DM |
| Electrical Builidng | Bldg. 1719 | 21-DN |
| General Purpose Warehouse | Bldg. 1614 | 21-DO |
| General Purpose Warehouse | Bldg. 1615 | 21-DP |
| General Purpose Warehouse | Bldg. 1616 | 21-DQ |
| General Purpose Warehouse | Bldg. 1702 | 21-DR |
| Fuse Detonator Magazine | Bldg. 1605 | 21-DS |
| Water Tower | Bldg. 1726 | 21-DT |
| Submerged Quench Incinerator | Bldg. 890 | 21-DU |
| Club Building | Bldg. T-831 | 21-DV |
| Garage | Bldg. 831A | 21-DW |
| Club Building | | 21-DX |
| Officer's Quarters | Bldg. 373 | 21-DY |
| Garage | Bldg. 373~~B~~A | 21-DZ |

TABLE OF CONTENTS

## CHRONOLOGY OF ROCKY MOUNTAIN ARSENAL ACTIVITIES

1942 Rocky Mountain Arsenal Established

1942-1945 Manufactured Chemical Agents and Incendiaries

- Mustard
- Lewisite
- Chlorine
- M74s Bombs
- M47s Bombs
- "Reworked M69s Bombs
- Phosgene Shells

1946 Rocky Mountain Arsenal placed in Standby Status

1947-1949 Portions leased to private chemical manufacturers

- Julius Hyman
- Shell Chemical Company

1947-1949 Demilitarization activities

- 155MM Shells
- 75MM Shells
- ANM76 Bombs
- M78 Bombs
- M79 Bombs

1950-1952 Rocky Mountain Arsenal reactivated for Korean War

- M74 (M20A1 Cluster) Bombs
- M31 Clusters
- E101 Clusters
- E101R1 Clusters
- M15 Hand Grenades
- White Phosphorus Cups
- M23 Fire Bomb Igniters
- Renovation of M19 Clusters

1953 Completed construction of Sarin (GB) complex

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| 1953-1957 | Manufactured Sarin (GB) and filled munitions |
| 1956 | Initiation of contamination cleanup efforts (Construction of Basin F) |
| 1957 | Sarin (GB) complex placed in Standby Status |
| 1960-1982/1983 | Hydrazine plant operation |
| 1964-1973 | Biological warfare activities<br>Storage, planting, and destruction of wheat rust spores |
| 1968-1976 | Disposal of chemical weapons<br>Project Eagle-Phase I (Mustard)<br>Project Eage-PhaseII (Sarin)<br>M34 Clusters (Sarin)<br>Weteye Bombs (Sarin)<br>Honest John Warheads M190 and M139 Bomblets (Sarin) |
| 1979-1982 | Demilitarization of chemical identification sets |
| 1983 | Cleanup investigations begin under Comprehensive Environmental Response, Compensation, and Liability Act "Superfund" |
| 1985 | Present cleanup actions for Rocky Mountain Arsenal underway |

## EXECUTIVE ABSTRACT

Construction of what became known as the Rocky Mountain Arsenal (RMA) began on June 19, 1942 and continued at a feverish pace until completion in 1944, costing about fifty million dollars. The work of constructing nearly three hundred buildings and installing complex machinery and processing equipment was facilitated through the extensive use of existing designs and professional expertise. During World War II, there were two major chemicals manufactured at RMA: mustard gas and Lewisite.

Besides chemical agent production during World War II, RMA had an extensive operation in the production and filling of incendiary bombs, used with enormous effect against both Germany and Japan. Bombs manufactured by RMA included the 10-pound oil bomb M74 and the 100-pound bomb M47. By the end of the war, RMA had produced more than one hundred thousand tons of incendiary bombs.

The Chemical Warfare Service faced a difficult decision when the war ended. The Service recognized that the reduced need for chemical agents and incendiary bombs would result in a vastly reduced budget. Alternatives, including "mothballing" RMA, were discussed, but the Service finally decided that it would be best to lease the facility to commercial operators who would provide maintenance and improvements. This option would allow the facilities to remain in operating condition in the event of another national emergency, in which case the plant could be reclaimed by the U.S. Government.

Cold War tensions exacerbated by the North Korean invasion of South Korea resulted in RMA being reactivated on June 25, 1950. During the conflict, RMA manufactured white phosphorus-filled bombs, artillery shells with distilled mustard, and incendiary cluster bombs. Of greater significance, though, was the decision to begin the manufacture at RMA of a highly toxic chemical product, known generically as nerve agent. This agent was known to produce systemic nervous system reactions usually resulting in death within a few minutes after exposure.

The nerve agent was known as Sarin or by the military designation, GB.[1] The Sarin manufacturing processes were conducted in RMA's Building 1501, a six-story, exposed-concrete structure. The facility, known as North Plants, consisted of 103 structures situated on a ninety-acre complex at RMA. It started production in 1953 and continued operations until 1957. As known from unclassified records, the plant cost 31,000,000 dollars to build and produce 500,00 gallons of Sarin. Without attempting to calculate indirect expenses and salaries, it would have cost about sixty dollars to kill a single person. The filling of munitions--shells and rockets-- with Sarin also started in 1953 and continued intermittently until 1969.

The safe disposal of chemical agents and the destruction of munitions filled with these products was another aspect of the RMA mission. This work started in the 1950s, but accelerated considerably following a 1968 Presidential Directive mandating the

[1]There are universal standards for classifying chemcial weapons. Nerve agents are classified in the "G" series; Tabun is the first of these nerve agents and so has a designation of "GA." Sarin is next and, so, has the designation, "GB."

destruction of obsolete chemical weapons. RMA was chosen as the site for the demilitarization of obsolete Sarin and mustard filled munitions, partly because of the expertise in the demilitarization operations that had been developed by Denver personnel, and partly because of the superior facilities located at North Plants.

By the early 1980s the principals--including the Department of the Army, the U.S. Environmental Protection Agency, the State of Colorado, and Shell Oil Company--found their differences irreconcilable and filed suit against each other in Federal district court. In 1988, an interim Consent Decree was signed by all parties, except by the State of Colorado, which defined their roles in cleanup as well as apportioning costs.

The Off-Post Record of Decision was signed on December 19, 1995, prescribing a number of remedies that focus on continuing the Off-Post Groundwater Intercept and Treatment System while ensuring an adequate and safe supply of water for the residents of Adams County, Colorado. This work will cost between 69-76 million dollars. The On-Post Record of Decision was signed on June 11, 1996, prescribing different remedies depending on the media involved--water, soil, air, biota, and buildings. The On-Post cleanup will cost 2.2 billion dollars; this amount will be apportioned between the Shell Oil Company and the U. S. Department of the Army. Once the cleanup has been completed in about ten years, 17,000 acres will be designated a National Wildlife Refuge, transferred to and managed by the U.S. Fish and Wildlife Service in accordance with the Rocky Mountain Arsenal Wildlife Refuge Act of 1992.

## BACKGROUND -- COLD WAR

With the breakup of the former Soviet Union and the end of the Cold War, it is difficult to remember the high tension, hysteria, and fear that characterized American society in the decades following the end of World War II. A new and alarming epoch of warfare began with the explosion of the first atomic device in the American desert; many Americans were horrified by the destructive force and human carnage seen in the first pictures from Japan. Americans took cold comfort in the fact that we were the only nation to possess this weapon, but our monopoly ended when the Soviets exploded their own atomic bomb.[2]

Nuclear bombs were not the only weapons of mass destruction known at the end of World War II. Through secret operations, the United States military learned that the Germans had developed a potent new chemical agent: nerve gases that killed quickly and effectively. The government was even more concerned when they discovered that German nerve gas production plants had been dismantled and reassembled in distant parts of the Soviet Union.

Americans during the Cold War decades were mostly preoccupied with atomic weapons and knew little, if any, about programs to develop and deliver chemical and biological agents. It was quite a different story for the military, though. The military opposed the prevailing national policy of not using chemical and biological weapons as

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[2]Paul Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (New York: Pantheon Books, 1985), pages 352-367.

part of our initial response strategy and were convinced that the Soviets "will probably use chemical, radiological and biological weapons singly or in combination in the event of hostilities."[3]

This retaliatory or deterrent policy remained in effect throughout the Cold War. The need for these weapons was unquestioned, however, and a high-level investigatory panel emphasized this fact, stating that the "vigorous development of agents and weapons in the BW [Biological Warfare] and CW [Chemical Warfare] fields is essential to the national security."[4] The Army continued to have this responsibility and the General Staff delegated the work to the Chemical Corps. Their mission was defined to include the discovery of "new and more toxic agents, to develop methods of synthesis, and to design manufacturing and filling plants" as well as "to adapt CW agent dissemination to improvements in aircraft, guided missiles, and ground weapons, to increase the efficiency

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[3]Major General Dwight E. Beach, General Staff, Director of Special Weapons and Requrements, ODCSOPS, to DCSLOG, September 12, 1958, Biennial Report of Major General William M. Creasy, Chief Chemical Officer, Record Group 319, Records of the Army Chief of Staff, Box 92, National Archives and Records Center, College Park, Maryland; Lieutenant Colonel Isham, Memorandum for the Chief of Staff, U.S. Army, November 22, 1949, Plans and Operations, Army Chief of Staff, Decimal File, 1949-1950, 384 Section I-H to 386.3, Box 257, Record Group 319, Records of the Army Chief of Staff, National Archives, College Park, Maryland.

[4]Major General A.C. McAuliffe, Chief Chemical Officer, Memorandum for the Chief of Staff, U.S. Army, Decimal Files, 1951-1952, 385.3, Record Group 319, Records of the Army Chief of Staff, National Archives and Records Center, College Park, Maryland; Report of Ad Hoc Panel on BW and CW, attached to Major General K. D. Nichols, GS, Chief of Research and Development, Memorandum for General John E. Hull, April 23, 1952, Decimal File, 1951-1952, 385 to 400 Case 45, Record Group 319, Records of the Army Chief of Staff, National Archives and Records Center, College Park, Maryland.

of both filling and containers in conventional incendiaries, and to increase the efficiency of aerosol generators."[5]

The Soviet threat in Europe and their likely decision to initially use nuclear, biological, and chemical weapons remained a paramount concern to us and our NATO allies. It was recognized, as well, by at least the 1960s, that the United States had a "very limited CW/BW warfare capability." As the director of Air Defense and Special Weapons in the Army General Staff Office reported: "Two major deterrents to US use of CW and BW are an inadequate stockpile of operational weapons, and inadequate detection capabilities . . . ." According to this report, "NATO's best strategy is to maximize the atomic capability and not divert atomic warhead carriers to chemical munitions." This was an opinion shared by our NATO partners, as General Maxwell Taylor found during a tour of Europe in March 1962. As a result of his "discussions with German, French, British, and SHAPE [Supreme Headquarters Allied Powers Europe] personnel, it became apparent that they consider [ed] the use of tactical nuclear weapons a key factor in the defense of Western Europe."[6]

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[5]Department of the Army, Research and Development Program, 1951, Program Director, Assistant Chief of Staff, U.S. Army, General Staff, U.S. Army, Top Secret Correspondence, 1948-62, 1950, 384 to 416, Record Group 319, Records of the Army Staff, Records of the Office of the Chief of Staff, National Archives and Records Center, College Park, Maryland.

[6]Study on Strategic Appraisal on Use of BW/CW Weapons, April 1, 1960, Prepared at the Direction of Chief of Staff, U.S. Army, Prepared by Atomic-CBR Division Office, Director of Air Defense and Special Weapons, ODCSOPS, Deputy Chief of Staff for Military Operations, General Correspondence, 1960, 280 B/C/R-LACROSSE, Box 55, Record Group 319, Records of the Army Staff, Records of the Office of the Chief of Staff,

While the deterrent threat of chemical weapons was not of significant strategic importance in Western Europe or elsewhere in the world, they were a needed part of our overall military posture, along with biological weapons. Today, they still pose a threat and a menace to our society, as can be seen from the recent terrorist bombing in the Toyko subway syste using the potent nerve agent Sarin. Their deleterious medical affects can be seen in the many soldiers who served during the 1991 multi-nation military campaign against Iraq known as Desert Storm, and were apparently exposed to these chemicals during their service there. We are just beginning to understand this problem and direct resources to help the apparently thousands of soldiers who continue to suffer from injuries and medical conditions produced from exposure to chemical agents.[7]

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National Archives and Records Center, College Park, Maryland; Lieutenant Colonel Albion W. Knight, Jr., General Staff, Memorandum for the Record, April 13, 1962, Report on Discussion with the Military Advisor for the President on Status of Tactical Nuclear Weapons, Deputy Chief of Staff Operations, General Correspondence, 1962-TAFFS, 280 AMMO, B/C/R, Box 45, Record Group 319, Records of the Army Staff, Records of the Office of the Chief of Staff, National Archives and Records Center, College Park, Maryland.

[7]*The Christian Science Monitor*, December 12, 1996, page 3.

# PART I: HISTORY

## INTRODUCTION

The United States has only made limited use of chemical weapons in combat. But, beginning in the 1920s and continuing until the recently concluded arms race, the possible employment of these weapons by others forced the United States to engage in significant research and development programs. Collaboration between the military and industry has been a key factor, and has enabled the United States to make effective use of foreign technology--particularly Germany's mustard and nerve gases. The concept of deterrent chemical weapons has been integral to America's overall military strategy throughout this century, but especially during the recent past. The United States produced massive quantities of a lethal nerve agent, matched it with an effective delivery system, and advised the former Soviet Union that it had this capability throughout the Cold War. The Rocky Mountain Arsenal-- as the only production source for this gas outside of the Soviet Union--had a significant role in national defense during the Cold War years.

## USES OF CHEMICAL WEAPONS (B.C.-1918)

### EARLY

Chemical agents belong to three distinct groups--gases, smokes, and incendaries. Gases are chemical agents which produce a direct harmful effect on people; a smoke agent is designed to provide some concealment for offensive opertions; and incendiary agents are used to ignite the surrounding material and produce destructive fires. Chemical agents are used in weapons of many different types to produce the desired effect. Biological agents include microorganisms like viruses, bacterias, funguses, and richettsiae that attack the human body, disrupting its processes and producing illnesses and death. In between the biological and chemical agents are toxins (botulinus, ricin, and tricothecene), the poisonous by-products of microorganisms--plants and animals.[8]

The use of chemical weapons can be traced back to the conflicts between the Athenians and Spartans in the fifth century B.C. Pitch, charcoal, and sulphur were heated together in cauldrons and the fumes were directed by bellows over enemy defenses. Somewhat later incendiary arrows were developed and employed with effect on wooden structures. The Byzantine Greeks formulated a secret compound known as "Greek Fire" that produced thick clouds of blinding smoke and poisonous vapors. It proved difficult to extinguish and the chemicals apparently bonded with water molecules, resulting in a more extensive fire. It was still in use at the time of the Crusades in the thirteenth century, but disappeared later when the formula was lost.

Both sides in the American Civil War experimented with chemical weapons, but since they often proved ineffective or unreliable, they were discontinued. Later in the nineteenth century, the British planned on using a poisonous gas during the Crimean

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[8]Augustin M. Prentiss, *Chemicals in War: A Treatise on Chemical Warfare* (New York, New York: McGraw-Hill Book Company, Inc., 1937), page 4; John Hemsley, *The Soviet Biochemical Threat to NATO* (New York, New York: St. Martin's Press, 1987), pages 122-123; James A. F. Compton, *Military Chemical and Biological Agents* (Caldwell, New Jersey: The Telford Press, 1987), pages 337, 355.

War to end the siege of Sebastopol. The potential carnage, particularly among the civilian population, convinced government officials to abandon this scheme.[9]

## GAS WARFARE IN WORLD WAR I (1914-1918)

Chemical agents were employed with limited effect early in World War I. Chlorine, classified as a "choking agent," because it produces respiratory failure, was the first gas used in the war. The Germans began experimenting with chlorine-filled shells in 1914 and dropped over three thousand of them on British troops near Neuve-Chapelle, with no effect. A modified 105mm howitzer round, known as a T-shell, was also used on the Eastern Front against the Russians. But due to the cold temperatures, the filling of xylyl bromide (tear gas) failed to vaporize. The Germans continued experiments with the T-shells as well as other chemical weapons.[10]

Fritz Haber, a German scientist and reserve army officer, convinced the German command that gas cylinders filled with chlorine could be an effective weapon. The Germans decided to employ this new technique and placed a number of cylinders, with the nozzles pointed toward the Allies, in their fortified trenches. On April 15, 1915, with

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[9]Major John W. N. Schulz, *Text-Book on the Chemical Service* (Fort Leavenworth, Kansas: The General Service Schools Press, 1922), pages 1-2; Kevin Takashi Fujitami, "The United States and Chemical Warfare: The 1925 Geneva Gas Protocol and Its Legacy" (Masters' thesis, Department of History, University of Hawaii, May 1991), page 27-31, copy on file at the Military History Institute, Carlisle, Pennsylvania.

[10]L. F. Haber, *The Poisonous Cloud: Chemical Warfare in the First World War* (Oxford, England: Clarendon Press, 1986), pages 24-25.

the wind blowing toward the enemy position at Ypres (Belgium), some 6,000 cylinders were opened and the chlorine gas drifted toward the Allies, enveloping a number of them in a deadly cloud. Those outside of the cloud soon saw their comrades "coughing and clutching their throats. Moments later French soldiers staggered by, "'blinded, coughing, chests heaving, faces an ugly purple color, lips speechless with agony.'"[11] Sir Arthur Conan Doyle reported to a shocked British nation several days later that the Germans "'took possession of . . . trenches tenanted only by the dead garrisons whose blackened faces, contorted figures and lips fringed with blood and foam showed the agonies in which they had died.'"[12] The modern era of gas warfare had begun.

Countries tried to develop protective equipment for their soldiers. The first gas masks were little more than cloth strips, moistened with water or sometimes other fluids. As one contemporary British soldier recalled his experience at Ypres (Belgium) in May 1915, "'We noticed clouds of greenish-yellow vapour rolling towards us from the enemy trenches. Hastily we 'moistened' and donned the respirators. Not wishing to use the precious water in my bottle, I used the alternative advised [urinating on the cotton waste], which luckily, I was able to provide for myself!'"[13] The French, at first, used this cotton waste as a mouthpad, known as a Black Veil. Before the end of May 1915,

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[11]Charles E. Heller, *Chemical Warfare in World War I: The American Experience, 1917-1918*, Leavenworth Papers No. 10 (Fort Leavenworth, Kansas: U.S. Army Command General Staff College Combat Studies Institute, September 1984), pages 6-9.

[12]Haber, *The Poisonous Cloud*, page 231.

[13]Donald Richter, *Chemical Soldiers: British Gas Warfare in World War I* (Lawrence, Kansas: University of Kansas Press, 1992), page 12.

the British had tested an impregnated wool helmet, complete with a celluloid window. In July British troops had been supplied with this Hypo helmet. By 1916 the British and Germans had developed a "respirator" mask that consisted of impregnated half face mask, padded goggles, and flexible tubing attached to a filter box containing charcoal and other materials. This became the standard mask for German, British and American troops; the French chose to develop and wear a mask that did not use filters.[14]

Since chlorine's field use was quite limited and could be effectively deterred by the conventional gas mask, chlorine was soon replaced by other agents.[15] The Germans responded to the Allied development of chlorine with a new choking agent--phosgene. Developed by the potent German chemical manufacturer I.G. Farben, phosgene produced delayed irreversible pulmonary edema, an accumulation of fluid in the lungs due to left-sided failure of the heart.[16] But improvements in gas mask design again provided effective protection against phosgene as well as other contemporary agents.[17] This tension between agent production and protection continued until the Germans employed a potent new toxic agent--mustard gas --in 1917.[18]

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[14]Haber, *The Poisonous Cloud*, pages 46-47, 67-77, 228.

[15]Compton, *Military Chemical and Biological Agents*, pages 113-115.

[16]Ibid., pages 119-121.

[17]Leo P. Brophy, Wyndham D. Miles and Rexmond C. Cochrane, *The Chemical Warfare Service: From Laboratory to Field* (Washington, D.C: Office of the Chief of Military History, United States Army, 1959), pages 61-62.

[18]Prentiss, *Chemicals in War*, pages 178-180.

## MUSTARD GAS IN WORLD WAR I (1917-1918)

Mustard is classified as a toxic vesicate or blister agent, which because of its low volatility is extremely persistent. The gas can remain in the immediate environment for days or even weeks and sometimes is carried with great effectiveness by the wind.[19] The oily vapor penetrated masks and clothing. Before the conflict ended about twelve thousand tons of mustard-smelling agent had been used, resulting in over four hundred thousand deaths among all the combatants.[20] Mustard is corrosive to human tissue both locally and systematically, resulting in death from lung damage and massive white blood cell destruction.[21] The Germans first used it in shells that were delivered against the

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[19]Whether a gas was defined as presistent or non-persistent, depended on the length of time that it remained effective at the point of release. Prentiss stated that the American standard before the start of World War II was that a persistent had to require protection for 10 minutes for it to be classified persistent; any shorter time frame and the agent was classifed as
non-persistent. Prentiss, *Chemicals in War*, page 10. According to Prentiss, *Chemicals in War*, page 178, "Vesicants, in general, are:

1. Nonspecialized in their action on the body, as they destroy the cellular structure of the
tissues wherever they come in contact with them.
2. Slow acting, in producing physiological effects on the body. . . .
3. Nonreversible in action, for their injury to the cellular structure of the tissues is permanent.. . .
4. Low in threshold of action. . . .
5. High in boiling point.
6. Low vapor pressure and volatility.
7. High in persistency.
8. Insidious in action . . . ."

[20]Prentiss, *Chemicals in War*, pages 180, 199.

[21]Compton, *Military Chemical and Biological Agents*, page 13. Besides distilled mustard (HD), the blister agents include: the Arsenicals, MD-- Methyldichoroarsine,

British forces at Ypres on July 12-13, 1917. Its effectiveness was apparent and the Germans fired tons of mustard-filled "Yellow Cross" shells against the Allies before the war's end. One contemporary estimated that the British gas casualties during the month following the introduction of mustard gas were almost as numerous as all gas casualties incurred during the early years of the war.[22]

LEWISITE (1917-1918)

The persistent and slow-acting qualities of mustard restricted its use. The Germans reacted by developing ethyldichlorarsine in 1917--a nonpersistent, quick-acting, toxic agent containing arsenic. The United States decided to improve this new agent and assigned Dr. W. Lee Lewis of Catholic University, Washington, D.C., to manage the project. The new arsenic containing vesicant compound that his team developed (chlorvinyldichlorarsine), soon known as Lewisite, was sent to Edgewood Arsenal, Maryland, the government's first chemical weapons plant. Production of Lewisite was initiated by the Army at Edgewood in the fall of 1918 and some product actually arrived

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PD-Phenyldichloroarsine, ED-Ethyldichloroarsine, and Llewisite [dichloro (2-chlorovinyl arsine], with arsenic as their principal atom; the Nitrogen Mustards, HN-1 2,2-dichlorotriethylamine,
HN-2 2,2-dichloro-N-methyldiethylamine, and HN-3 2,2,2-trichlorotriethylamine, which are ammonia derivatives; Oximes, CX phosgene oxime; and Mixes, HL mustard-lewisite and HT mustard-T mix. Compton, *Military Chemical and Biological Agents*, pages 6-86.

[22]Amos A. Fries and Clarence J. West, *Chemical Warfare* (New York, New York: McGraw-Hill Book Company, Inc., 1921), page 151.

in Europe as the war ended in November 1918.[23] Continued refinement of Lewisite as well as the threat posed by mustard were important reasons why the United States decided both to accelerate chemical agent research and consolidate functions in one agency.

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[23]Ibid., pages 190-191, 37; W. Lee Lewis and G. A. Perkins, "The Beta-Chlorovinyl Chloroarsines," *Industrial and Engineering Chemistry*, Volume 15 (1923), page 290.

## CHEMICAL WARFARE SERVICE (1917-1943): FORMATION (1917-1918)

Even after the United States entered World War I, the responsibility for chemical warfare was ineffectively divided among the Bureau of Mines, Medical Department, Ordnance Department, Signal Corps, Corps of Engineers, and the American Expeditionary Force. The first step in coordination occurred in the fall of 1917, when the Army established the Gas Service, composed of the Medical, Ordnance, and Chemical Service Section personnel. The Gas Service, however, still could not control research, policy, or production. The War Department finally recognized the organizational problems in May 1918, and appointed Major General William L. Sibert head of the Gas Service. Sibert was instructed to develop recommendations for better coordination of chemical warfare. He believed that only through merging all related functions into one organization could this be done. Sibert lobbied effectively for an integrated chemical warfare program. In June 1918, President Woodrow Wilson approved Sibert's proposal and a unified chemical warfare organization--Chemical Warfare Service (CWS)--was established as part of the National Army.[24]

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[24]Leo P. Brophy and George J.B. Fisher, *The Chemical Warfare Service: Organizing for War* (Washington, D.C.: Center for Military History, 1989), pages 8-12..

## CHEMICAL WARFARE SERVICE: EDGEWOOD ARSENAL (1917-1918)

The War Department initially expected that private industry would manufacture toxic gases under Ordnance Department supervision and only shell filling would be done by the government. Erection of the first government shell filling plant at Edgewood, Maryland started in September 1917, was completed by January 1918, and the plant immediately started filling shells. When it became apparent by the end of 1917 that the chemical industry could not meet the military demand, the War Department decided to build its own manufacturing plants at Edgewood. The Edgewood Arsenal, as the growing facility was known, produced quantities of chloropicrin, phosgene, mustard gas, chlorine, and sulphur monochloride before the end of the war.[25]

## CHEMICAL WARFARE SERVICE: AT THE BEGINNING OF WORLD WAR II (1939-1942)

With the beginning of hostilities in Europe in 1939-1940, the CWS felt the need to reorganize so that it could be prepared for the expected military intervention of the United States. The CWS did not feel that this new organizational structure was working, so it reorganized again in July 1941. Three "services"--Industrial, Field, and Technical--reported directly to the Chief. In turn, the services were comprised of several divisions,

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[25]Benedict Crowell, *America's Munitions, 1917-1918* (Washington, D.C.: Government Printing Office, 1919), pages 395-410; Colonel F.M. Dorsey, "The Development Division, Chemical Warfare Service, U.S.A.," *Industrial and Engineering Chemistry*, Volume 11 (1919), pages 281-91; Brophy, *Chemical Warfare Service: From Laboratory to Field*, pages 14-17.

of which the Manufacturing, Construction (Industrial), CWS Technical Committee, and Research and Engineering (Technical) divisions were most involved with the work at Rocky Mountain Arsenal. When the Army reorganized in March 1942, the CWS was placed in the Services of Supply which was later changed to Army Service Forces Command. The other "commands" were the Army Air Forces and the Army Ground Forces.[26]

CHEMICAL WARFARE SERVICE:
THE NATIONAL RESEARCH DEFENSE COUNCIL (1940-1942)

The CWS also accelerated its research program and began collaboration with university laboratories, including the Massachusetts Institute of Technology, Columbia University, and the University of Chicago.[27] Early on a symbiotic relationship was forged between the CWS and the National Research Defense Council (NDRC). The NDRC was established in 1940 to undertake those scientific problems for which the military did not have adequate resources. The NRDC assumed a powerful role in both proposing projects as well as serving as the liaison to academia and industry. The CWS

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[26]Chemical Warfare Service, *The Chemical Warfare Service in World II* (New York, New York: Reinhold Publishing Company, 1948), pages 20-23.

[27]Brophy, *Chemical Warfare Service: From Laboratory to Field*, pages 36-38; George H. Mangun, "Toxicity Laboratory, University of Chicago," *Armed Forces Chemical Journal*, I (January 1947), pages 25-26, 49-50.

and the NRDC, additionally, formed a joint Technical Committee in 1942 to oversee all research and development work in chemical warfare.[28]

CHEMICAL WARFARE SERVICE:
CHEMICAL WEAPONS TESTING FACILITIES (1942-1943)

Testing facilities were needed, as well, and the Edgewood Arsenal, near populous Baltimore, Maryland was deemed unsuitable for chemical weapons experiments. So an isolated site in northwestern Utah, that included part of the Dugway Valley, was selected. Dugway Proving Ground became the principal site for the field testing, proof firing, and surveillance of chemical agents and munitions under temperate zone conditions.[29] For tropical testing, smaller facilities were established at Camp Paraiso in the Panama Canal Zone and in central Florida outside the sleepy village of Bushnell.

[28]Irvin Stewart, *Organizing Scientific Research for War: the Administrative History of the Office of Scientific Research and Development* (Boston, Massachusetts: Little, Brown and Company, 1948), pages 7-8. The NRDC was reorganized in 1942 and Divisions 9 (Chemistry), 10 (Absorbents and Aerosols), and 11 (Chemical Engineering) were principally concerned with work at RMA. Stewart, *Organizing Scientific Research for War*, pages 60, 88-90. W. A. Noyes, Jr., editor, *Chemistry: A History of the Chemistry Components of the National Defense Research Committee, 1940-1946* (Boston, Massachusetts: Little, Brown, and Company, 1948), pages 145-149.

[29]Bernard Baum, "Dugway Proving Ground," IN Historical Branch, Chemical Corps School, *History of Research and Development of the Chemical Warfare Service in World War II*, Volume 23 (Edgewood Arsenal, Maryland: Historical Branch, Chemical Corps School, 1947), page 285.

Toward the end of the conflict an "experimental station" was established on San Jose Island, off the west coast of Panama.[30]

## CHEMICAL WARFARE SERVICE: INCENDIARY WEAPONS (1941)

Responsibility for incendiary weapons was divided between the CWS and Ordnance Department by order of the War Department in 1920. Neither command vigorously pursued research and development of these weapons in the interwar years. This situation changed significantly, though, when General Porter assumed command of the CWS Service in May 1941. Porter was convinced that incendiaries would be absolutely essential in the war effort. Porter soon appointed Professor J. Enrique Zanetti of Columbia University, who had studied incendiaries since the end of World War I, to head the putative Incendiary Branch. Porter also successfully lobbied senior military advisors and they agreed to place all responsibility for incendiary weapons with the CWS.[31]

## EXPANSION OF THE ARSENAL SYSTEM (1941)

The Edgewood Arsenal was the only facility capable of manufacturing chemical agents when European hostilities started. The CWS had planned that if war occurred

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[30]Brophy, *Chemical Warfare Service: From Laboratory to Field*, pages 40-41.

[31]Brophy and Fisher, *The Chemical Warfare Service: Organizing for War*, pages 43-45, 96-97.

another arsenal would be needed and by the summer of 1941, a site in the Tennessee Valley near Huntsville, Alabama, had been selected. There, near the end of July, construction of the new arsenal was begun. The decision of the Army Chief of Staff to place the responsibility for the incendiary bomb program with the CWS, forced military planners to decide whether to use industry or build additional arsenals. The decision, motivated at least in part by the unsuccessful experience from World War I, was to use government plants. A pilot incendiary bomb plant was built at Edgewood in the fall of 1941, and about the same time work started on a full-scale facility at Pine Bluff, Arkansas.[32] In the expanded arsenal system, Edgewood became a pilot plants operation while facilities at Huntsville, Pine Bluff, and Rocky Mountain manufactured toxic agents, smoke and incendiary material, and with these filled shells, grenades, smoke pots, and bombs.[33]

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[32]Ibid., pages 255-258.

[33]Brophy and Fisher, *The Chemical Warfare Service: Organizing for War*, pages 120-121.

## ROCKY MOUNTAIN ARSENAL (1942-1945): BACKGROUND (1942)

The need to expand further military production capability resulted in the CWS looking at additional sites, including those west of the Mississippi. The site chosen was located about ten miles northeast of downtown Denver, Colorado, on land then being used primarily for agricultural purposes. This site was selected for a variety of reasons including: 1) it could not be easily reached by enemy bombers; 2) availability of a mix of technical and semi-skilled workers; 3) cheap and adequate supply of both process and potable water; 4) network of county, state, and federal highways; 5) access to the main line of the Chicago, Burlington, and Quincy Railroad; 6) a temperate climate; 7) acceptable topographic, geologic, and soil conditions; 9) sufficient electrical power provided from the Public Service Company of Colorado and the Rural Electrification Administration; 10) existing telephone service which could be readily upgraded; and 11) the undeveloped and inexpensive land--20,000 acres--was readily available.[1]

Based on the recommendation of the Plant Site Board, Major General William N. Porter, Chief of the Chemical Warfare Service requested and received authorization from the Secretary of War on May 12, 1942, for the "establishment of a new arsenal at

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[1]Army Service Forces, Chemical Warfare Service, *History of Rocky Mountain Arsenal* 57 Volumes (Typescript, 1945-1980), Volume I, part 1, page 3, copy on file at the Technical Information Center, Rocky Mountain Arsenal, Commerce City, Colorado (hereafter cited as *RMA History*). "Report on Site Investigation made for the Chief of Engineers of the U.S. Army by Prouty Bros. Engineering Co. Consulting Engineers, Exchange Bldg., Denver, Colo.," May 5, 1942, File Drawer,"Rocky Mountain Arsenal, 1942-1945", Historical Office, Edgewood Arsenal, Maryland.

Denver, Colorado, for the production of certain gases and loading facilities." This decision was made just six months after the United States entered World War II. Along with the authorization, some sixty-two million dollars was appropriated to cover construction costs.[2]

Funds for land acquisition were handled separately and ultimately 474 individual tracts were purchased under condemnation proceedings. The existing records, including photographic documentation, show that many of the families were engaged in subsistence agriculture mixed with some cattle ranching and dairy farming [See HAER No. CO-21 drawing 2 of13 "Pre-Arsenal Period, 1936"].[3] By June 1942, the first thirty-five families living in what was designated as the 5,000-acre "central tract" had left their homes. Most of these families recognized that they were contributing to the war effort and willingly relocated. Their cooperation, the *Denver Post* stated, "has been most satisfactory."[4] But it was not easy leaving your home and farm. The twelve-year-old

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[2]*RMA History*, Volume 1, part 1, pages 4-5; *Denver Post*, May 24, 1942, pages 1, 7.

[3]*RMA History*, Volume 13. Twenty-two structures, including the Rosehill School, were left and used by the Army. *RMA History*, Volume 1, part 1, page 37. For an overview of the Arsenal's prehistory, see Nickens and Associates, "An Archeological Overview and Management Plan for the Rocky Mountain Arsenal, Adams County, Colorado (Atlanta, Georgia: National Park Service, May 14, 1984), page 2-11-2-17, copy on file at Rocky Mountain System Support Office, National Park Service, Denver, Colorado. See forthcoming report from Rocky Mountain System Support Office, National Park Service, Denver, Colorado, for information on the historic period prior to 1942. This report is being completed under contract for the National Park Service.

[4]*Denver Post*, July 29, 1942, page 4, microfilm on file at the Western History Collection, Denver Public Library, Denver, Colorado.

Lucille Egli recalls that her stern, Swiss father wept openly when the day arrived that his family had to leave their home of some thirty years.[5]

## ROCKY MOUNTAIN ARSENAL: CONSTRUCTION (1942-1944)

The Army Corps of Engineers (COE) took over supervision of military construction from the Quartermaster Corps in December 1941, the same month that the Japanese bombed Pearl Harbor. Following a general army reorganization in March 1942, Engineers were placed in the newly formed Service of Supply command.[6] In June 1942, COE was directed to manage construction of Arsenal facilities. Contract negotiations for the prime construction contractor and architect-engineer were handled by the COE at Huntsville. The Area Engineer Lieutenant Colonel Carl H. Breitweiser of the Construction Division, was sent, along with Huntsville COE officers, including Colonel W. J. Ungethuem, E. C. Thompson, John O'Hehir, and representatives from of the contract firms, to open an office and begin work.

Civilian contractors did most of the work. Whitman, Requardt, and Smith of Baltimore, a firm with experience at Huntsville, and H.A. Kuljian and Company of

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[5]Video tape of Egli sisters [Gladys, Rose, and Lucille], February 22, 1996, copy on file at the Public Relations Office, Rocky Mountain Arsenal, Commerce City, Colorado.

[6]Blanche D. Coll, Jean E. Keith, and Herbert H. Rosenthal, *The Corps of Engineers: Troops and Equipment* (Washington, D.C.: Center for Military History, 1975), pages 132-136.

Philadelphia were selected to do most of the design, contract negotiations, and contract supervision. H. K. Ferguson Company of Cleveland did the design work for the Chlorine and Thionyl Chloride plants; Kershaw, Heyer, Swinerton, and Walberg of San Francisco and Denver had the same responsibility for the M69X Incendiary Bomb Plant. The technical requirements of designing specialized process equipment was handled through separate contracts with E. I. DuPont de Nemours and Company of Wilmington, Delaware. Kershaw, Swinerton, and Walberg managed the construction work.[7] The district office of the Corps assisted with follow-up projects, completed between 1943-1944.[8]

When work was finally completed in 1944, the Arsenal included the following buildings clustered by function and situated at various locations throughout the twenty-thousand acre site:

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| Area "A" | Permanent Administration | Buildings 111 - 116 |
| Area "B" | MP Barracks (Now WCW School) | Buildings 121 - 135 |
| Area "C" | Main Gate Area | Buildings 141 - 149 |
| Area "D" | Temporary Administration Area | Buildings 151 - 169 |
| Area "E" | Staff Quarters | Buildings 171 - 176 |
| Area "F" | Prisoner of War Area | Buildings 181 - 199 |

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[7]Headquarters U.S. Army, Rocky Mountain Arsenal, Denver, Colorado, Undated, Unsigned memorandum, General Administrative Files, 08-29-19-4-3, Box 50, undated, unmarked folder, ca. 1951, National Archives, St. Louis, Missouri (hereinafter cited as RMA BACKGROUND); *RMA History*, Volume 1, part 1, pages 5, 7, 9; James W. Du Pont, "The Du Pont Company and National Defense," *Armed Forces Chemical Journal*, Volume 10, Number 2, (March-April, 1956), pages 20-21.

[8]*RMA History*, Volume 1, part, 1, pages 5, 7, 9. Colonel Carl H. Jabelonsky served from May 1942 - October 1943; Lieutenant Colonel S. R. Harmer served from October 1942 - July 1944.

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|---|---|---|
| Area "G" | Chem. Mfg. and Filling Area Plants | Buildings 241 - 543 |
| Area "H" | Depot, Shop and Storage Area | Buildings 611 - 698 |
| Area "J" | Incendiary Bomb Area | Buildings 725 - 785 |
| Area "K" | Magazine Igloo and Toxic Yard | Buildings 811 - 886 |
| Area "L" | Areas, Buildings and Structures Otherwise unclassified[9] | |

Area A, known as the Permanent Administration Area, was located on December 7th Avenue, west and north of the chemical plants. The principal structure in this complex was the Administration building (No.111), which has been modified over the years. The MP Barracks Area was first built to house the military police detachment, subsequently it was used by the Western Chemical Warfare School. The administration building (T-131) and the supply building (T-132) were farm structures that predated the Arsenal. The Main or Derby Gate Area was located at the west entrance to the Arsenal on December 7th Avenue and A Street. The Prisoner of War complex was located on 6th Avenue between B and C streets. The Rose Hill School was converted into the administration building and other structures were used by the military police who relocated there in 1944. The Chemical Manufacturing and Filling Plants were located on two hundred sixty acres in the center of the Arsenal site. Also located within this area were the facilities for incendiary weapons manufacturing. The Depot, Shop and Storage area was located in the southwest section of the Arsenal. This area included Paint (622), Carpenter (623), and Machine (624) shops, along with miscellaneous storage buildings, and a switching system that provided connections with the C.B. and O. and Union

[9]*RMA History*, Volume 1, part 1, page 38.

Pacific railroads. The rail line was extended to provide service to the plants area as well as the Toxic yard. The Magazine, Igloo, and Toxic Storage Yard were located on F Street north of December 7th Avenue. The Toxic Gas Yard provided open storage for agent filled containers. Shells and bombs were stored in the fifteen magazines or six igloos. In addition there were a number of miscellaneous buildings like the cafeteria (311), fire and police station, Central Analytical Laboratory, laundry, infirmary, and motor pool.

ROCKY MOUNTAIN ARSENAL:
THE WAR YEARS: Manufacturing chlorine, mustard, lewisite, M74 bombs, M47 bombs, phosgene shells, and reworking M69 bombs (1942-1945)

During the war, workers at Rocky Mountain Arsenal manufactured the following chemical weapons and incendiaries: chlorine, mustard, lewisite, M74 bombs, M47 bombs, phosgene sheels, and reworked M69 bombs.

To organize this effort, on June 2, 1942, the new arsenal staff began operating out of offices on the fourth floor of the Cooper Building in downtown Denver, with Lieutenant Colonel Marshall Stubbs in the role of commanding officer. Stubbs, along with his military staff and civilian workers, was preparing to manufacture mustard, lewisite, and incendiaries for the war effort. The organization filled out the following day when an Adjutant, Captain J. F. Lane and Transportation Officer, First Lieutenant George R.

Jones reported for duty.[10] Hiring of civilian workers started on June 5, and Raymond Monahan was hired first, as a messenger.[11] By the end of the week, Lieutenant Colonel Breitweiser had arrived from the Huntsville Arsenal to assume the duties of Area Engineer. Breitweiser took over the two recently acquired Adams City and Derby school buildings for his staff as well as the contractors and others from the CWS. He was joined the next week by Colonel Ungethuem. The importance of the arsenal was recognized with the appointment of Colonel Charles E. Loucks as the commanding officer in August 1942. Loucks was sent to the new facility from his position as Executive Officer, Office of the Chief, CWS. An officer with the CWS since 1925, he had attended the Massachusetts Institute of Technology and received a Master of Science degree in 1931. He had significant experience with chemical weapons production during his eight years of service at Edgewood Arsenal, part of which he was Technical Director.[12]

Staff was hired first for the Chlorine Plant. The senior civilian Chlorine Plant operators were recruited through the cooperative efforts of area universities and the Great Western Sugar Company. Most of the operators were undergraduates, majoring in

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[10] *Chemical Warfare Service Newsletter*, August 1942, page 24, copy on file at Historical Office, Edgewood Arsenal, Maryland (hereinafter cited as CWS *Newsletter*).

[11] "Post Diary, 1942-1945," copy on file at Technical Information Center, Rocky Mountain Arsenal, Commerce City, Colorado, page 2 (hereinafter cited as "Post Diary"). This is a compilation of information about the Arsenal from 1942-1945, organized chronologically.

[12] Ibid., page 3; CWS *Newsletter*, August 1942, page 24.

general science. They were older than the typical student and had practical experience gained from working in oil refineries, sugar factories, war plant construction, and mining. The workers, though, did not have much transferable practical experience and they experienced difficulty in adjusting to working with hazardous materials. Operators first completed a fifty-hour Emergency Science Management War Training Course in chemistry taught by the University of Colorado, in cooperation with the War Department. Some people were then sent to Huntsville Arsenal while others went to the Hooker Electrochemical Company chlorine plant in Niagara Falls, New York. Operators also received practical training in special topics such as brine treatment, cell repair, cell operation, evaporation, and caustic fusion.[13]

Besides the Chlorine Plant operators, about five hundred people initially applied for work and of this number some one hundred were hired. Many of the people hired locally did not have any experience in chemical plant operation and these workers were given academic courses at the University of Colorado and other area universities. These courses included a two- to six-week course for inexperienced chemical engineers; a one-week course in analytical procedures for chemists; a four- to eight-week course at factories for instrument makers and refrigerator plant operators; and a one-month course in chemical plant operations. Women received separate training, and in November 1942, a class started for those working as technicians in the various chemical

[13]*RMA History*, Volume 8, pages 2452-2454; R. Wolcott Hooker, "The Story of Hooker Electrochemical Company," *Armed Forces Chemical Journal*, Volume 10, Number 1(January-February 1956), pages 22-27.

laboratories. Night-time chemistry classes were given at the University of Denver, as the first offering.[14]

The raising of the flag at the administration building on January 5, 1943, was marked by a formal ceremony and was an occasion for the accomplishments of the arsenal to be noted. State and local dignitaries joined the staff and members of the Iron Workers Union, who had constructed the building. The ceremony was presided over by newly promoted Brigadier General Loucks. Major General William Porter, Chief of the CWS, arrived the next day and told the community that RMA "will play an important part in winning the war, when and if the Axis starts [sic] using war gas."[15]

Production of other chemicals started in early 1943, which occurred at the same time that the Allies were winning the war in Africa. On March 10th, the first acetylene was manufactured; two days later, the first Sulphur Monochloride was manufactured; and on March 16th, the first batch of Lewisite was finished. And before the end of the month, the Incendiary Oil Bomb (IOB) buildings had been completed. The next month, April, chlorine was first manufactured and the IOB plant started operations before the end of the month.[16]

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[14]CWS *Newsletter*, October 1942, page 21; "Post Diary," pages 4, 6; Leo P. Brophy, "Training Civilian Workers in Wartime," *Armed Forces Chemical Journal*, Volume X, Number 5 (September-October 1956), page 36.

[15]Ibid., February 1943, page 19; "Post Diary," page 7.

[16]"Post Diary," pages 8-9.

Many women worked on the "lines" as well in other plant operations and provided a crucial source of labor during World War II. The *Denver Post* estimated that seventy percent of the wartime Arsenal jobs were held by women.[17] These women proved their worth under stressful conditions and learned to handle the complex machinery and hazardous chemicals as well as male workers. For many of them plant work was a novel undertaking and their experience contributed to changing the work world in the post-war period. "Rosie the Riveter," the symbol of women's "can-do" attitude, was expressed throughout RMA.[18]

The government soon recognized that there were not enough male soldiers to both fight battles and handle the myriad assignments needed to make American forces function. To meet this latter need, women were enlisted for noncombatant duties in the Women's Auxiliary Army Corps (WAAC) by an act of Congress in May 1942. The first WAAC officer, Captain Martha R. White, reported for duty in the Personnel Division in

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[17]*Denver Post*, May 11, 1945, page 12, microfilm on file at the Western History Collection, Denver Public Library, Denver, Colorado.

[18]Susan M. Hartmann, *The Home Front and Beyond: American Women in the 1940s* (Boston, Massachusetts.: Twayne Publishers, 1982), passim; Shema Berger Gluck, *Rosie the Riveter Revisited: Women, the War, and Social Change* (Boston, Massachusetts.: Twayne Publishers, 1987), passim; D'Ann Campbell, *Women at War with America: Private Lives in a Patriotic Era* (Cambridge, Massachusetts.: Harvard university Press, 1984), passim; Kaylene Hughes, "Women at War: Redstone's World War II Female 'Production Solders'" paper presented at the U.S. Army Historians Conference, June 1994; Karen Anderson, *Wartime Women: Sex Roles, Family Relations, and the Status of Women during World War II* (Westport, Connecticut: Greenwood Press, 1981), pages 3-22.

October 1943; she was joined the next month by eighteen other female officers, who were given temporary assignments at RMA.[19]

Typical of these wartime women were Marge Brandow and Pete Fox. These sisters were in their twenties when they reported for work at the Incendiary Oil Bomb (IOB) plant in early 1944. They had previously worked at the Denver Remington Arms factory and changed jobs because the RMA facility was closer to their home. They worked together in a booth and the drama of filling bombs with napalm was soon replaced by the tedium of line work. They passed the time with endless renditions of *Three Little Fishes* and other popular songs. Marge and Pete recognized the importance of their work and felt that it was their way of contributing to the war effort. They did not remember receiving any training, but did recall that they had to wear blue coveralls, which Marge stated "smelled terrible", safety shoes, and an army fatigue hat. The women sometimes autographed the finished bombs and even wrote their names and addresses on the casing. Marge recalls seeing a World War II photograph of one of their signed bombs being released from an American bomber over Germany.[20]

Only the military personnel lived on post, the civilian work force left RMA each afternoon or evening to return to their homes. But some arsenal workers did socialize together during their off-duty time. Typical of the wartime parties was an ice cream

[19]"Post Diary," page 15.

[20]Video tape of Marge Brandow and Pete Fox, February 20, 1996, copy on file at the Public Relations Office, Rocky Mountain Arsenal, Commerce City, Colorado.

social hosted by the Arsenal women just before Thanksgiving, complete with live music provided by the military police detachment.[21] As the weather turned warm, the men of the military police detachment used some of their free time to form a softball team and enter the Metropolitan Softball League. The military police also sponsored Miss Jere Johnson in the state-wide Pin-Up contest, with judging at the Colorado State Fair. After winning the contest, the MPs declared that Johnson was also the Army Pin-up Girl for the State of Colorado.[22]

The need for humor on the job prompted Lieutenant Colonel E. J. Sullivan to use the talents of Bill Parse, a civilian employee of the Plant Safety Branch of the Inspection and Security Division, to create cartoon characters who were regularly featured on posters. "Dopey Joe" was the title for a mythical worker who took excessive breaks, extended lunch periods and performed little work. He was followed by the "Chemlin," an "impish doer of evil" who "plugs pipes, interferes with production, blows out fuses, misfiles papers . . . ."[23] Everyone, of course, worked very hard not to be a "Dopey Joe" or the "Chemlin."

The Arsenal was also designated as a Prisoner of War Camp on November 6, 1943, and the Rose Hill School building was converted into the administration building (T-181). The construction of the remaining facilities was not completed until January

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[21]CWS *Newsletter*, January 1943, page 49.

[22]"Post Diary," pages 11-12.

[23]CWS *Newsletter*, May 1943, page 14.

1944. Initally, twenty-six prisoners were sent there, probably Germans. By December the number of prisoners had increaed to one-hundred; a military police detachment consisting of twenty-two enlisted men and two officers were assigned to guard them.[24] Marge Brandow and Pete Fox, two sisters who worked at RMA from January 1944 to the end of World War II, stated that there were about five hundred German and Italian prisoners at the Camp. They recall that the Camp was surrounded by a chain link fence and that the prisoners did little more than "cut weeds," but the official Arsenal history notes that they were used in many other ways. Connie Martin, who arrived at the Arsenal as young woman just out of high school, recalled that the prisoners were transferred from the Camp, presumably on a train, in March 1946; the official Arsenal history states that the Camp was discontinued on April 1, 1946.[25]

Colonel Maurice E. Jennings, Commandant of the West Coast Chemical Warfare School, inspected RMA in October 1943, to determine what facilities were available for use by the proposed Chemical Warfare School.[26] Later in the month, the West Coast Chemical Warfare School located at Camp Beale, California, was transferred to RMA and the name was changed to the Western Chemical Warfare School. In June the first class started with fifty-five enlisted men.

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[24]Ibib., page 17; RMA History, Volume 2, Part 1, page 404.

[25]Video tape of Marge Brandow and Pete Fox, February 20, 1996, Video tape of Connie Martin, February 21, 1996, copy on file at the Public Relations Office, Rocky Mountain Arsenal, Commerce City, Colorado; RMA History, Volume 18, page 220.

[26]"Post Diary," page 17.

Before the end of the war the government again showed its appreciation for the Arsenal contribution to the war work. The civilian employees of RMA were recognized for their efforts at a special ceremony held on June 30th. General Loucks represented the Secretary of War and Major General William Porter, Chief of the CWS, in presenting an Army-Navy "E" Award to RMA employees for "excellence of production." And a separate event occurred in early May 1944, when Brigadier General Alexander Wilson assumed command of the Arsenal, replacing General Loucks who returned to the Office of the Chief of the CWS, in Washington.[27]

Tragedy struck RMA at the same time. On June 5, 1945, two of the new M74 bombs exploded on the pyrotechnic bomb assembly line, burning six women employees. One of them, Nora R. Ruiz, died later at Fitzsimons General Hospital. Three others were seriously burned and had to be hospitalized at Fitzsimons where they received treatment for their burn injuries. Two women received only minor burns and, after receiving emergency treatment at the RMA dispensary, they returned to work. General Wilson was at a loss to explain the accident and when questioned about it, stated that the "bombs simply blew up; that's all we know." There was no damage to the bomb assembly building.[28] Work on incendiaries and the other activities continued at RMA through the end of hostilities in August 1945.

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[27]Ibid., pages 19-20.

[28]*Denver Post*, June 6, 1945, page 1, microlfim on file at the Western History Collection, Denver Public Library, Denver, Colorado.

## ROCKY MOUNTAIN ARSENAL: WARTIME RECORD

Rocky Mountain Arsenal fulfilled its wartime mission as a chemical weapons manufacturing facility. It was managed by the Chemical Corps, using civilian labor. Women worked throughout the various plants and significantly contributed to the work accomplished by the Arsenal. Distilled mustard, Lewisite, and Chlorine were manufactured there. When it became apparent that these chemicals were not likely to be employed by either side in World War II, the Arsenal began manufacturing napalm and PT-1. These mixtures were used to fill incendiary bombs--M74s and M47s. These weapons were used with great effect both in Europe and against the Japanese. Arsenal workers also "reworked" M69s bombs, manufactured elsewhere, as well as filling shells with phosgene gas. At the end of the war, the Arsenal faced an uncertain future, but the beginning of the "Cold War" and the threats posed by the Soviets would ensure that the Denver facility would continue to exist.

## USE OF CHEMICAL AND INCENDIARY WEAPONS IN WORLD WAR II: DECISION NOT TO USE CHEMICAL AGENTS (1942-1945)

While the United States dropped atomic bombs on Japan, it never used chemical agents against them or the Germans. The cruel deaths and injuries attributed to chemical agents in World War I seemingly convinced subsequent peacetime presidents that gas warfare was immoral. President Franklin D. Roosevelt supported this policy and stated that this country's position was that it would not use chemical agents *unless* they were first employed by our enemies. A different view prevailed within the Chemical Warfare Service and Major General Porter repeatedly urged them to be used against the Japanese. The military, though, initially opposed this view, not on moral, but military grounds, fearing that such use would provoke a retaliatory bombardment of England and Russia by the Germans. As casualties mounted in the Pacific, some senior generals within the military changed their position. General George C, Marshall, Army chief of staff, favored the use of chemical agents. Once the Germans surrendered in May 1945, he found others who supported his view, including General Douglas MacArthur, commander in the Pacific. Still, other military leaders raised fierce moral objections and these arguments proved compelling to the new president, Harry S. Truman. He decided to use nuclear rather than chemical power to end the war with Japan.[29]

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[29]Barton J. Bernstein, "Why We Didn't Use Poison Gas in World War II," *American Heritage*, Volume 36 (August/September 1985), pages 41-45.

## USE OF INCENDIARY WEAPONS (1942-1945)

The ban on chemical agents did not extend to the use of incendiary weapons and these were effectively employed against the Germans and Japanese in numerous bombing raids. The M69 was extensively used in the Pacific against the Japanese. More than thirty million of them were manufactured and over 750,000 clusters--with 14, 38, or 60 of the 6-pound bombs--were dropped on Japanese cities.[30] Major General Curtis LeMay of the XXI Bomber Command dropped 400 tons of M69s on Toyko alone in February 1945. The intelligence debriefing showed that the M69s had destroyed or damaged about 1 square mile of the urban area and this persuaded Lemay to adopt the policy of low-altitude bombing using incendiaries. In a massive raid staged on March 9, 1945, 300 of LeMay's bombers dropped nearly two tons of incendiaries, mostly M69s, on Toyko. Subsequent reconnaissance photographs showed that 16 square miles of the city had been destroyed, including over twenty-five percent of all standing structures. And before the war ended, American bombers had dropped more than 100,000 tons of incendiaries on Japan, again, most of them were M69s.[31] The military estimated that incendiaries alone had destroyed the Japanese war economy. The damage included over

[30]Chemical Corps Association, *Chemical Warfare Service in World War II: A Report of Accomplishments* (New York, New York: Reinhold Publishing Corporation, 1948), page 25.

[31]Wesley Craven and James Leon Cate, eds., *The Army Air Force in World War II*, Volume 5, *the Pacific: Matterhorn to Nagasaki* (Chicago, Illinois: University of Chicago Press, 1953), chapters 18, 20, 21, 23; Kohn and Harahan, eds., *Strategic Air Warfare*, page 5; LeMay *Mission with LeMay*, page 352.

158 square miles of Japan's urban industrial areas and left an estimated 8,480,000 people homeless. Nearly forty percent of every city hit by incendiaries was destroyed![32]

M47s also were used effectively against enemy targets. At least some of the bombs were clustered and delivered to their target in packages of six bombs. Over two million of the M47 bombs were eventually produced and used in both the European and Pacific Theaters. Among the most famous bombing missions was the strike by Flying Fortresses in October 1943 against the Fockewulfe aircraft assembly plant at Marienburg, East Prussia. In this raid, some 1,300 M47s were dropped on the target and resulted in the total destruction of the facility. The bomb was used with devasting effect on other German targets, including Schweinfurt, the roller bearing plant, and the Ploesti oil refineries in Rumania.[33]

Incendiary materials are usually classified as either "intensive" or "scatter" type. An intensive agent is one that is ignited, rather than detonated, and the burn is confined. Intensive agents were designed to burn for a extended period and did so intensely; whereas with scatter agents the filling is dispersed some distance, with reduced burning time and diminished intensity. The advantage of scatter agents was that they could ignite materials some distance from the original point of contact.[34] Magnesium had been

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[32]Chemical Corps Association, *Chemical Warfare Service: A Report of Accomplishments*, page 25.

[33]Ibid., page 27.

[34]George J. B. Fisher, *Incendiary Warfare* (New York: McGrawHill Book Company, Inc., 1946), page 32. Fisher was a colonel in the Chemical Warfare Service during WWII.

accepted as tbe best metal for casings since the Germans developed an alloy mixture bomb near the end of World War I. Magnesium reacts quickly with oxygen and begins to burn vigorously when the melting point of 1204 degrees Fahrenheit is reached. Magnesium vapor subsequently produces a temperature of 3630 degrees Fahrenheit, igniting all available combustible material in the immediate area.[35]

## ROCKY MOUNTAIN ARSENAL (1945-1983): THE IMMEDIATE POSTWAR YEARS (1945)

The high spirits and unity among the former allies immediately following the end of World War II quickly dissipated. England's former Prime Minister Winston Churchill had always been dubious of the Soviet Union's intentions and be voiced his concerns in a speech delivered in Fulton, Missouri in the early spring of 1946. While Churchill tried not to be overly provocative, his comment that an "iron curtain" bad descended upon Eastern Europe did resonate among Western officials and further alienated Stalinist Russia.[36] Among those wbo probably agreed with mucb of Churchill's assessment was George F. Kennan, wbo bad considerable experience in working with the Soviets. In 1947, Kennan, as "Mr. X", authored an article on the nature of Soviet power and its implications for the United States. In the article, Kennan used the now famous word

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[35]Ibid., pages 33-34.

[36]Kenneth Ingram, *History of the Cold War* (New York, New York: Philosophical Library, 1955), pages 30-33.

"containment" to express his preference for dealing with the Soviets.[37] President Harry S. Truman said that this was too narrow a focus and "we were working for a united, free, and prosperous world." However, our recent allies, the Soviets, "have other ideas. They are out to dominate the world."[38] This growing anti-communist feeling was fueled by politicians climaxed by the high theater of the McCarthy hearings. The American sense of security fostered by our monopoly of atomic weapons was shattered when the Soviets detonated their own nuclear bomb in the early 1950s.[39] Military planners and civilian leaders began to realize that the United States had to develop weapons and delivery systems that would provide the ability to retaliate with force even after a surprise attack by the Soviets. This "deterrence" strategy embodied in the Strategic Air Command and Polaris submarines, depended on sophisticated weapons like the newly developed hydrogen bomb and second-generation highly toxic chemical agents.[40]

But production of new chemical weapons or any role for the Arsenal was uncertain when the war in the Pacific ended on August 15, 1945. At that time all activity at the

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[37]George F. Kennan, *Memoirs, 1925-1950* (Boston, Massachusetts.: Little, Brown, and Company, 1957), pages 355-367.

[38]*Memoirs by Harry S. Truman: Years of Trial and Hope*, 2 Volumes (Garden City, New York: Doubleday & Company, 1956), Volume 2, page 290.

[39]Richard Rhodes, *Dark Sun: the Making of the Hydrogen Bomb* (New York, New York: Simon & Schuster, 1995), passim.

[40]Richard H.Kohn and Joseph P. Harahan, editors, *Strategic Air Warfare: An Interview with Generals Curtis E. LeMay, Leon W. Johnson, David A. Burchinal, and Jack J. Catton* (Washington, D.C.: Office of Air Force History, United States Air Force, 1988), pages 90-131, passim; General Curtis E. LeMay, *Mission with LeMay: My Story* (Garden City, New York: Doubleday & Company, Inc., 1965), 427-500, passim.

various plants at the Denver facility ceased, except for some short-term work at the H (mustard) Distillation Plant and Fifth Echelon Repair Shop. The Shops's function had resulted when the CWS realized that it did not have the resources to repair the equipment that was being sent from Europe to the Far East. It was decided to establish the first such shops at RMA in the fall of 1944. The only suitable buildings available at the time were six warehouses of the 350 series (351-356 [See HAER No. CO-21-AZ]). Work on smoke generators and flamethrowers was underway by December 1944 and continued until May 1945, when the lack of parts forced personnel to stop, except where they could "cannibalize" spare parts. As broken equipment began returning from the Pacific, it was sent to the Fifth Echelon Repair Shops where it was repaired.[41]

## CHEMICAL AGENT PLANTS: STANDBY STATUS (1946)

The Arsenal staff and CWS senior officers decided that the remaining surplus crude Levinstein mustard needed to be distilled so that the innovative Denver plant operation could show results. Once the Distillation Plant completed processing of the crude mustard on October 31, 1946, it was placed in "standby under power" status. The other plants placed in this same status included the Chlorinated Paraffin, Chlorine, H Manufacturing, and M69X incendiary bomb facilities. Some facilities were removed, including the M74, M14 (WP) Igniter, AN-M9 (WP) Igniter, and M76-500 (PT-1), and

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[41]RMA History., Volume 11, page 3600, 3611, Volume 18, page 12, and Volume 9, part 2, pages 3121-3125.

were relocated at other arsenals--either Pine Bluff or Huntsville. Other facilities were moved from locations throughout the country where they had been operated by various private companies and reassembled at RMA.[42]

[42]Ibid., Volume 11, pages 3612-3614.

## A NEW MISSION (1945-1982)

While the Arsenal was completing chemical equipment repair work, distilling the remaining mustard, and placing plants in standby status, the headquarters of the CWS, in the summer of 1945, surveyed all of the country's arsenals. Following the completion of this survey, the CWS decided that RMA would be retained for the purpose of continued production of chemical agents and weapons. The civilian work force was reduced from a wartime high of 3,100 men and women in August 1945 to about 600 people by the fall of 1950. The Chemical Corps staff was similarly reduced. In May 1946, the 1736th Service Command Unit stationed in Denver was transferred to RMA, consisting of 5 officers and 150 enlisted men.[43] They were later joined by a small detachment of the 216th Chemical Service Company, attached to the 92nd Chemical Service Company.

Consistent with their new mission, RMA was assigned responsibility for:

1. Processing industrial reserve components and equipment for extended storage;
2. Reconditioning ton containers;
3. Reconditioning AN-M76 bombs;
4. Rehabilitating decontaminating apparatus;
5. Placing plants in stand-by condition;
6. Demilitarization of chemical weapons.

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[43]The Chemical Warfare Service renamed the Chemical Corps on August 2, 1946; in May 1962, the Chemical Corps was disestablished and the functions were subsumed under the newly created Army Materiel Command.

## DEMILITARIZATION OPERATIONS (1946-1982)

By 1947 RMA had received orders from CWS headquarters to begin "demilitarization" operations on chemical weapons being sent to them from other locations throughout the United States. Demilitarization would continue to be a major part of the work done at RMA for many years. [See HAER No. CO-21 drawing 6 of 13 "Demilitarization: South Plants, 1947-1974."]

## DEMILITARIZATION OPERATIONS--155MM SHELLS (1946-1949)

Mustard filled 155MM shells were among the first weapons to be "demilled". Arsenal personnel began studying the problem in the summer of 1946 in anticipation of their new assignment and decided to use converted facilities in the Mustard Distillation Plant (Thaw House; Building 537) for this work. A production line of conveyors and related equipment was installed and operations commenced on September 16, 1947. The shell was unloaded from shipping crates and the burster well plug, charge and, finally, well were removed. The filling of crude Levinstein mustard was then emptied from the shell casing into a reservoir and then pumped into one of four receiver tanks. The final process step involved dumping the mustard into reconditioned one-ton containers. The one-ton containers were loaded on to trucks for transfer to storage areas at RMA. Meanwhile, the shell casings were decontaminated with concentrated sulfuric acid and the metal sold for scrap. The last of this shipment of shells were processed in January

1949.[44] The conveyor line and equipment were modified to accommodate 105MM shells and work was started on them in February 1949, and was completed the following month. The plant was then decontaminated and was in the process of being placed in "stand-by" status when orders were received to complete "demil" for an additional 61,000 155MM shells. The work started on May 31, 1950 and concluded a few months later.[45]

## DEMILITARIZATION OPERATIONS--75MM SHELLS (1949)

RMA was given the responsibility, too, for the safe processing of thousands of mustard-filled 75MM shells. The equipment was installed in part of the Mustard Distillation Plant in Building 538 (Drum Disposal). Construction of the 75MM "line" was started in March 1949 and completed the next month. This plant operated like the 155MM facility. Shells were first checked for a burster charge, then the shells then moved along the line and the copper rotating bands were removed. The casings were then heated in a hot water bath tank to facilitate removal of the mustard. Next, the heated casings were sent along a power-and-roller conveyor to the press room where they were spliced into two equal sections and the filling was transferred into reservoirs and subsequently into one-ton containers. The casing proceeded along screw conveyors

[44] *RMA History.*, Volume 19, page 256, Volume 20, page 23, Volume 21, page 78, Volume 24, page 84.

[45] Ibid., Volume 25, page 80, Volume 26, page 90.

and passed through solutions of concentrated sulfuric acid. Any visible contaminants were removed by passing the casing through the solutions again.

The scrap was sold and hauled away by private contractors. The metal was a valuable commodity. Colonel C.M. Kellogg, commander of the Denver arsenal, made sure that his superiors in Washington recognized his entrepreneurial efforts by explaining to them that the recovery of mustard from the 77MM shells had been financed entirely through the sale of casings. The plant concluded operations near the end of December 1949, having processed some 1,018,058 shells.[46]

## DEMILITARIZATION OPERATIONS--AN-M76 (1947)

RMA rehabilitated chemical bombs, as well. The AN-M76, was a steel-cased, 500-pound bomb, filled with either 115 pounds of IM or 180 pounds of PT-1[47]. It was used effectively to destroy industrial structures and nearly eighty thousand of them were dropped on the Germans and Japanese.[48] On March 11, 1947, RMA received orders from headquarters to rehabilitate these bombs, manufactured at other arsenals. Building

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[46]Ibid., Volume 24, pages 88-89, Volume 25, page 84; Colonel C.M. Kellog, Chemical Corps Commanding, Rocky Mountain Arsenal, to Chief, Chemical Corps, Washington, D.C., July 22, 1949, Demilitarization of H and CNS Filled 75mm projectiles, General Administrative Files, 08048-31-43, Box "13," National Archives, St. Louis, Missouri.

[47]The 500- Pound AN-M76 was a 475-pound bomb designed to hold 175 pounds of PT-1 filling; it had a 10.2 pound charge composed of tetryl (1.2 pds) and White Phosporus (9.0 pds); it had two fuzes: a nose impact AN-M103 and a tail inertia AN-M101A2. Office of Scientific Research and Development, *Effects of Impact and Explosion*, page 366.

[48]Brophy, Miles, and Cochrane, *The Chemical Warfare Service: From Laboratory to Field*, pages 180-181.

732, originally constructed as the main facility for the M69X Plant, was modified internally and additional equipment installed to handle the heavy casings. Both the "receiving" and "acceptance" tracks were fabricated by the Denver arsenal's Engineering Service Division.

The bombs were delivered to Building 732 by trucks and off-loaded on to a conveyor. As the bomb proceeded down the "line," the fuse cup, tail assembly, and rolling rings were removed, the burster well was cleaned, and finally the bomb casing was inspected for leaks and excessive rust. As the bombs were sent along the acceptance conveyor, they were stenciled, the rolling rings were replaced, the burster well was protected from rust by painting and closing the ends, and the casing was given a coded paint to correctly identify it as an incendiary.[49]

## DEMILITARIZATION OPERATIONS--M78 AND M79 BOMBS (1948)

Another 500-pound bomb, the M78, filled with phosgene, a nonpersistent, delayed-action agent, was also sent to Denver for rehabilitation. Phosgene bombs were designed under CWS specifications by the Ordnance Department in early 1942. The prototype was sent to Dugway Proving Ground in 1943 and tests demonstrated its effectiveness. The CWS filled 25,000 M78s in 1944; 63,000 of the massive 1,000 pound M79s were

[49] *RMA History*, Volume 20, pages 211-213.

filled by the Service between 1943-1945.[50] As the bombs arrived from other depots, they were visually inspected and divided into three categories: unserviceable; repairable; and serviceable. Unserviceable bombs were opened and the phosgene transferred to one-ton containers; the empty casings were decontaminated and the metal sold for scrap. Serviceable bombs were considered to be those M78s and M79s that only needed painting and stenciling. These bombs were reloaded onto trucks and transported to storage facilities located at RMA. Repairs were done on the remaining bombs; these bombs were painted, stenciled, and send to storage. Some 1,721 Phosgene bombs were inspected and reconditioned between July and December 1948.[51]

At about the same time, Building 331 at the Phosgene Plant was being used to transfer the chemical agent from defective "Type E" one-ton containers which were leaking into reconditioned "Type A" one-ton containers. A vacuum system was installed in the building to complete product transfer, a brine tank used was established to cool leaking containers with bad valves. About 300, one-ton containers were found to be defective. After the phosgene was removed, the bomb casings were either repaired or sold for scrap. The work was completed between April and July 1948.[52]

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[50]NRDC, *Chemical Warfare Agents, and Related Chemical Problems*, page 5; Brophy, Miles, and Cochran, *The Chemical Warfare Service: From Laboratory to Field*, pages 54-55.

[51]*RMA History*, Volume 24, page 72.

[52]Ibid., Volume 22, page 32; Ebasco Services, Inc., et al, *Final Volume II, Structures Profiles, Structures Survey Report, Section 2.2b Buildings 331-395 (South Plants)*, Prepared for U.S. Army Program Manager's Office for Rocky Mountain Arsenal Contamination Cleanup (Commerce City, Colorado: Rocky Mountain Arsenal, 1988), "Building 331".

LESSEES (1947-1949)

Along with its new mission of demilitarization of various chemical weapons, the Army decided that some plants at RMA could be leased to industry and they would bear the cost of maintenance for these plants, rather than using public funds. The contracts subsequently negotiated stipulated that should there be a national emergency that the leased plants could be returned to military use. One of the first companies to use this arrangement was Julius Hyman and Company, a firm producing insecticides. They were attracted to the Arsenal because of the existence of chemical processing equipment that could be easily adapted to their needs. They decided to establish their corporate headquarters there and used facilities like the Chlorine Plant for the production of insecticidal chemicals. Another lease was issued to H. O. Freundenberg and Russell D. George for the use of Building 523 to process perlite ore into plaster aggregate, which they marketed under the trade name Persolite.[53]

LESSEES--SHELL CHEMICAL COMPANY

Chemicals became powerful weapons in the war against insects. The first insecticides were used against the Colorado potato beetle in 1865. Subsequent research and products into the early 20th Century focused on inorganic compounds and inhibitors that resulted in muscle paralysis and death. These products directly attacked the insect nervous system, while later research focused on destroying nerve transmission. Among

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[53]Captain Clarence B. Wiley, "Rocky Mountain Arsenal," *Armed Force Chemical Journal*, Volume 4 (January 1951), pages 13-14.

these insecticides were aldrin and dieldrin developed in the United States by 1948 and manufactured by Shell Chemical Company at the Arsenal.

The Germans developed a more potent nerve blocker. Gerard Schrader, working for the German firm I.G. Farben, became studying the effects of organophosphates in the 1930s. Not only did his new compound effectively kill insects by disrupting nerve function, it resulted in a new generation of war gases that could be used on humans (See subsequent discussion on Sarin). Based on German research, organophosphorus compounds with commercial applications as insecticides first appeared in 1945. The first of these insecticides were tepp and parathion, followed shortly thereafter by malathion.[54]

Shell Chemical Company (SCC) acquired Julius Hyman's interests at RMA in 1952 and have remained to the present time. They recognized the benefit of using the Arsenal's existing buildings and equipment that could be readily and cheaply converted to commerical applications. Shell also may have been attracted to the site based on the prospect of providing the government with dichlor. During 1952-1953 SCC assisted the Army by producing this intermediate used in the manufacturing of Sarin. The work was done in buildings formerly used to distill mustard. Besides using existing South Plants structures, SCC constructed 150 buildings for use in its commercial chemical operations.

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[54]Edmund P. Russell, III, " 'Speaking of Annihilation': Mobilizing for War Against Human and Insect Enemies, 1914-1945," *Journal of American History* (March 1996), page 1519; A.W.A. Brown, *Ecology of Pesticides* (New York: John Wiley & Sons, 1978), pages 2-7.

SCC, at least for a short time, was engaged in work that produced chemicals that killed both humans and insects.

The chemicals manufactured by SCC, include

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|---|---|
| Aldrin | 1955-1974 |
| Dieldrin | 1955-1973 |
| Endrin | 1955-1965 |
| Methyl parathion | 1957-1967 |
| Ethyl parathion | 1964-1966 |
| Azodrin | 1965-1975 |
| Phosdrin Insecticide | 1956-1973 |
| Bidrin Insecticide | 1963-1975 |
| Ciodrin Insecticide | 1962-1973 |
| Vapona Insecticide/DDVP | 1960-1975 |
| Nemagon Soil Fumigant | 1955-1975 |
| Dibrom | 1962-1970 |
| Supona Insecticide | 1963-1967 |
| Planavin Herbicide | 1966-1975 |
| Gardona Insecticide | 1966-1968 |
| Akton Insecticide | 1967 |
| Landrin Insecticide | 1969 |
| Bladex Herbicide | 1970-1971 |
| Nudrin Insecticide | 1973-1975[55] |

[55]Harland Bartholomew and Associates, Inc., and Gilbert/Commonwealth, Inc., "Property Inventory and Survey Report for the Group I Chemical Plant Property within the Shell Oil Company Leasehold Area at US Army Rocky Mountain Arsenal, December 28, 1982" Commerce City, Colorado, Volume 7, Group I Chemical Plant Property Buildings on Shell Leasehold, copy on file at Technical Information Library, Rocky Mountain Arsenal, Commerce City, Colorado; Casimir Kuznear and William L. Trautman, History of Pollution Sources and Hazards at Rocky Mountain Arsenal," U. S. Army, Rocky Mountain Arsenal, September 1980, page 63, copy on file at the Technical Information Center, Rocky Mountain Arsenal, Commerce City, Colorado; "Plant Operation Summary," Shell Chemical Company, August 1, 1975, copy on file at the Technical Information Center, Rocky Mountain Arsenal, Commerce City, Colorado. Much of the information and data about Shell Chemical Company operations at RMA is still restricted.

## THE KOREAN WAR (1950-1952)

The Cold War suddenly became "hot" when hostilities erupted in Korea in 1950. While an official declaration of war was never passed by Congress, the United States committed forces and equipment to assist the South Koreans.[56] In August 1950, RMA was "reactivated" from its "standby" status of the past five years specifically to produce incendiary munitions needed by the armed forces.[57]

Both military and civilian personnel increased to over one thousand people and several filling programs were initiated. Connie Martin, then a personnel specialist, later recalled that numbers swelled even further and that before the end of the Korean conflict, there were about two-thousand-eight-hundred people at RMA.[58] Distilled mustard was supposed to be used to fill 105 and 155MM artillery shells but protracted problems kept the filling delayed until August 1952. Bomb manufacturing was also done and this work included both the M74 (M20A1 cluster; 20,000); M31 cluster (72,000); E101 cluster (25,000); and E101R1 cluster (36,000) as well as renovation of the M19 cluster (35,000).[59]

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[56]U. S. Army, *Area Handbook for South Korea* (Washington, D.C.: U.S. Government Printing Office, 1993), Chapter 1.10: The Korean War, 1950-1953.

[57]*RMA History*, Volume 29, page 29-5.

[58]Video tape of Connie Martin, February 21, 1996, copy on file at the Public Relations Office, Rocky Mountain Arsenal, Commerce City, Colorado.

[59]*RMA History*, Volume 30, pages 2-4, 92-100.

Tragedy struck the Arsenal again. Connie Martin later recalled that on October 31, 1951, a flash fire erupted on the M19 line when a careless worker tossed a denotator into the black powder bin. Connie remembers that between 82-85 women were burned, many of them receiving disfiguring injuries, and 2 women died from their extensive burns.[60]

The White Phosphorus Filling Plant resumed operations in October 1951 and before the end of the year had filled 738,659 cups. White phosphorus hand grenades (M 15) were scheduled items and nearly five-hundred thousand were eventually produced. Renovation work was done, as well, on the existing supplies of M19 clusters and just over thirty thousand were reworked by May 1952.

RMA personnel were busily engaged, too, in the scheduled manufacture of over four-hundred thousand M23 fire bomb igniters.[61] These furious days and nights of anxious activity ended in the fall of 1952 and RMA resumed its "standby" role, except for the work underway at the Incendiary Oil Plant (North Plants).[62]

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[60]Video tape of Connie Martin, February 21, 1996, copy on file at Public Relations Office, Rocky Mountain Arsenal, Commerce City, Colorado.

[61]*RMA History.*, Volume 30, pages 2-4, 92-100.

[62]Ibid., Volume 31, page 1.

## SARIN (1937-1959)
### BACKGROUND

Sarin and its equally deadly cousin, Tabun, may have been known as early as 1902, but their deadly potential was not realized until the 1930s. At that time Dr. Gerhard Schrader of I. G. Farben, a German chemical company, was experimenting with chemicals based on organophosphorus bondings. During routine laboratory testing in January 1937 a drop of Tabun spilled and produced symptoms that included severe respiratory distress. More tests followed, the German military intervened, and the potential of Tabun as a chemical weapon was established. A production facility was established at Elberfeld in the Ruhr in late 1937 under the control of the German Army; in 1940. Agent manufacturing continued at a secret installation at Dyhernfurth-am-Oder near Breslau in Silesia throughout World War II. The German Army inducted Schrader and directed him to continue nerve agent experiments. The next year he developed a more potent compound and named it after his research team: S[chrader], A[mbrose], R[udriger], and van der [L]in[de]. Sarin was produced on a limited basis at an experimental plant at Dyhernfurth.[1]

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[1]Compton, *Military Chemical and Biological Agents*, pages 144, 151; Joseph Borkin, *The Crime and Punishment of I. G. Farben* (New York, New York: The Free Press, 1978), page 132; Affidavit of Otto Ambos, May 1, 1947, NI-6788, Reel 52, Record Group 238, National Archives Collection of World War II Crimes Records, T-301, Records of the United States Nuremberg War Crimes Trials United States of America v. Carl Krauch et al. (Case VI), August 14, 1947-July 30, 1948, page 16, National Archives and Records Center, College Park, Maryland (hereinafter cited as Crimes Records); Affidavit of Philip Heinreich Hoerlein, May 2, 1947, NI-6787, Reel 52, Crimes Records.

Sarin works on the body's nervous system through inhibition of the enzyme cholinesterase. Without this enzyme, acetylcholine, used in the parasympathetic nervous system, accumulates at the neurons and produces continuous stimulation. Persons affected experience loss of bodily functions, accompanied by respiratory failure. Sarin is fatal, often in less than one minute, and acute dosage is about one drop on the skin or an equivalent amount inhaled. Sarin is five times heavier than air and is a non-persistent agent with high volatility[2]

Even before the end of hostilities in Europe, the allies began preparations for a blitzkrieg of a different sort. Britain and the United States intended to send special intelligence teams into targeted areas of Germany in a collaborative venture known by the code name "Paperclip." They would interrogate German scientists and engineers, particularly those engaged in atomic weapons and rocket research, as well as appropriating any promising technology.

Chemical weapons were also of interest to the allies. Lieutenant Colonel Paul Tarr, the intelligence chief of the CWS, was attached to a team headed by Commander A. K. Mills of the British Ministry of Aircraft Production. Colonel Tarr was directed to investigate operations of the giant German chemical manufacturer, I. G. Farben. His questioning finally forced the firm's staff to reveal the existence of a new class of chemical weapons--nerve agents. Shortly thereafter, Tarr found Gerhard Schrader. The German scientist, possibly in exchange for immunity, gave the formulae for both Tabun

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[2]Compton, *Military Chemical and Biological Agents*, pages 135, 153.

and Sarin to Tarr. Schrader also advised the American officer that the Russians has just captured the experimental Sarin plant at Dyhernfurth, including the laboratory's notebooks and process documents.[3]

THE FIVE STEP PROCESS AND DICHLORO (ca. 1947-ca.1949)

The United States adopted Sarin (also known by the designation: GB) as its standard nerve agent.[4] To produce Sarin, the Chemical Corps somewhat modified the German 5-step process, Dimethyl Hydrogen Phosphite [DMHP]. The chemicals used to produce Sarin include chlorine, fluorine, phosphorus trichloride, hydrogen fluoride, methane methanol, and isopropanol. In Steps I-III, phosphorus trichloride reacted with methyl alcohol in the presence of methyl chloride. This produced dimethyl hydrogen phosphite which was pyrolyzed to form methylphosphonic dichloride--known more simply as "dichloro". The responsibility for producing the intermediate dichloro was assigned to the Tennessee Valley Authority (TVA) at their Muscle Shoals Plant. But until the plant achieved production, the intermediate was manufactured by Shell Chemical Company using leased buildings at RMA. TVA provided Shell with data for the Aluminum Chloride Process that the latter used to manufacture the intermediate. After the

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[3]Tom Bower, *The Paperclip Conspiracy: the Battle for the Spoils and Secrets of Nazi Germany* (London, England: Paladin Gradton Books, 1988), pages 105-108; Linda Hunt, *Secret Agenda: The United States Government, Nazi Scientists, and Project Paperclip, 1945 to 1990*
(New York, New York: St. Martin's Press, 1991), pages 12-14.

[4]Compton, *Military Chemical and Biological Agents*, pages 151-152.

Muscle Shoals Plants was in production, dichloro was shipped in railroad cars across the country to RMA where Steps IV-V took place. These process steps involved the fluorination and treatment with isopropyl alcohol of the dichloro to produce the final product--isopropyl methylphosphonofluoridate.[5]

## CONSTRUCTION OF PRODUCTION PLANT AT RMA (1951-1953)

The Chemical Corps decided that the final process steps would be completed at RMA, where there was adequate security, storage, handling, and safety. Design of the secret facility, referred to as the Oil Incendiary Plant, was done by Kellex Corporation (subsequently Vitro Corporation of America) in 1950. Vitro collaborated with Universal Oil Products; the Chemical Corps and the Corps of Engineers jointly supervised the project. Colonel William J. Allen, who commanded the Arsenal from 1958-1961, and was then working at Edgewood, later stated that the failure to first construct a pilot plant created many subsequent problems at the North Plants facility.[6] [See HAER No.

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[5]A. R. Hylton, " Studies on the Technical Arms Control Aspects of Chemical and Biological Warfare: The History of Chemical Warfare Plants and Facilities in the United States", Volume IV (Midwest Research Institute, November 13, 1972), microfilm RMA RSA 019, on file at the Technical Information Center, Rocky Mountain Arsenal, Denver, Colorado, pages 4, 6-8, 59-60 [microfilm 497, 499-501, 552-553]. Much of the information and data regarding the development and manufacture of Sarin is still in the classified records at RMA as well as the classified records of the Chemical Corps, RG-175, National Archives and Records Center, Suitland, Maryland. None of this material has been referenced in this report.

[6]*RMA History*, Volume 29, pages 73-74; Volume 30, page 10; Volume 31, page 43; Hylton, "History of Chemical Warfare Plants," pages 1, 60-61, 69-71, 75 [microfilm 494, 553-554, 562-564, 568]. Video tape of Colonel William Allen and wife, February 21, 1996,

CO-21 drawing 7 of 13 "Chemical Production: GB (SARIN) Nerve Agent Production and Filling" and also drawing 12 of 13 "North Plant".]

Construction started in 1951, the facility was tested the next year, and production started in the summer of 1953. The facility cost 25,000,000 dollars to construct and it required an additional 6,000,000 dollars to complete the test run as well as prepare for "standby" status. North Plants produced 500,000 gallons of GB, all of which was manufactured in 1954. Vitro estimated that it would require over 2,000 people to operate the plant, but there were only 400 employed there during the peak operating year in 1954. By 1957 this number had been reduced to 250 people when preparations for placing the facility in standby or layaway status had been completed.[7]

RUSSIAN NERVE GAS PROGRAM (1945)

The Soviets sent the captured plant equipment and laboratory documents back to the Karpov Institute in Moscow. The Soviets also captured the other secret nerve agent plant at Falkenhagen and transported it back to Russia where it was reassembled. And by the end of 1946, Soviet production facilities for the nerve agent Soman had been completed. Subsequent analysis based on different types of data confirmed that the

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copy on file with Gary Hall, Public Relations Office, Rocky Mountain Arsenal, Commerce City, Colorado.

[7]*RMA History*, Volume 29, pages 73-74; Volume 30, page 10; Volume 31, page 43; Hylton, "History of Chemical Warfare Plants", pages 1, 60-61, 69-71, 75 [microfilm 494, 553-554, 562-564, 568].

Soviets had supplies of Tabun and Sarin as well as VR-55, likely a potent form of Soman. That they possessed multiple delivery systems consisting of rifle-fired shells as well as rockets and bombs is unquestioned.[8] A significant part of our Cold War strategy was shaped around the concept of "massive deterrence." Since the United States knew that the Soviets had nerve agents, we had to establish our "deterrent" stockpiles. So, according to this reasoning, if the Soviets used deadly chemical weapons, they would be faced with our retaliation.[9]

## NERVE AGENT AND RMA WORKERS (1954-1959)

Frank DiGiallonardo, a young pipe fitter and World War II veteran, transferred from the Julius Hyman operation to North Plants in 1954 and remained there until 1959. He recalls that they used to work wear longjohns and then donned thick rubber suits,

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[8]C. J. Dick, "Soviet Chemical Warfare Capabilities," *International Defense Review*, Volume 14, No. 1 (1981), pages 31-32, 35-36; Defense Intelligence Agency, *Soviet Chemical Weapons Threat* (Washington, D.C.: Defense Intelligence Agency, 1985), pages 3, 13; John Erickson, "The Soviet Union's Growing Arsenal of Chemical Warfare," *Bulletin of the Atomic Scientists*, Volume 30 (September 1974), page 64; Robert Jarman and Philip Jarman, "Soviet Chemical Warfare: A Present Danger," *Defense and Foreign Affairs*, Volume 11(June 1983), page 34. Soman was a compromise between the persistent Tabun and non-persistent Sarin. Compton, *Military Chemical and Biological Agents*, page 158.

[9]Mark E. Smith, III, et al., eds., *American Defense Policy*, 2nd Edition (Baltimore, Maryland.: The Johns Hopkins Press, 1968), pages viii, 15-20, 29-113, passim; Richard G. Head, et al., eds., *American Defense Policy*, 3rd Edition (Baltimore, Maryland.: The John Hopkins Press, 1973), pages 6-19, 99-125, 181-187; Steven T. Ross and David Alan Rosenberg, *America's Plans for War Against the Soviet Union, 1945, 1950,* Volume 9, *The Atomic Bomb and War Planning: Concepts and Capabilities* (New York, New York: Garland Publishing, Inc., 1989), page 97; Henry Kissinger, *Diplomacy* (New York, New York: Simon & Schuster, 1994), pages 608-610.

complete with full hood, rubber gloves and shoes, and respirator, before they entered the bays. They worked in teams of two people, with an outside "operator" who constantly monitored them. They were only allowed to work in the bays for fifteen minutes and then had to go through decontamination procedures--a caustic shower followed by a rinsing one. Their used suits were washed again and thoroughly checked for leaks before they were used again. Even with this precautions, many men were exposed and had to use the atropine antidote. DiGiallonardo remembers giving himself the "shot" on three different occasions when he experienced GB symptoms, especially respiratory distress. According to Frank DiGiallonardo the Arsenal with all its problems was still a "premium job" and he believes that the government did everything possible to protect him and his fellow workers.[10]

HYDRAZINE PLANT FOR MISSILE FUEL (1960-1982/1983)

Besides the production and destruction of chemical weapons, the Arsenal worked on producing missile fuel. In July 1960, representatives of the U. S. Air Force and the contractor building the Titan II missile, the Glenn Martin Company (now Lockheed Martin), met with Arsenal personnel to explain their requirements for a hydrazine blending plant. Two months earlier, the Air Force had awarded Martin a new contract to develop an advanced version of the existing Titan missile. Known simply as Titan II,

[10]Video tape of Frank DiGiallonardo, February 20, 1996, copy on file with Gary Hall, Public Relations Office, Rocky Mountain Arsenal, Commerce City, Colorado.

the new missle, designed to carry a heavier warhead greater distances with more accuracy than its precedessor, was to he propelled with a improved fuel mixture: hydrazine and unsymmetrical dimethyl hydrazine (UDMH). The Titan I missile was, in 1960, employed in various military installations in the midwest and west, including a site at Lowery Air Force Base, on the edge of metropolitan Denver, Colorado. The Titan I used a fuel mixture that was hoth unstahle and had to be mixed just prior to the missile's launch. The new fuel mixture, which included an oxider, nitrogen tetroxide, overcame these prohlems, allowing the new Titan II to be launched immediately.

The Air Force wanted the Arsenal to construct a temporary hlending plant and needed it to he operational by Octoher 1960. The Air Force wanted to transport hydrazine and unsymmetrical dimethyl hydrazine (UDMH) to the Arsenal, where they would be blended, creating a propellant known as Aerozine 50. The mixture would then he analyzed. If it met Air Force specifications, it would he shipped in their tank trucks to military sites retrofitted with the Titan II missiles.

Construction of the facility started on August 24, 1960, and was completed in November, at a cost of $80,000. The hlending unit was provided under a separate contract with the Food Machinery Corporation of San Jose, California and delivered to the Denver site in October 1960. The lack of on-site storage facilities proved to he a significant prohlem and the solution involved construction of a tank farm for the raw materials and the final product. The tank farm cost $460,000 to construct and the work was completed under the supervision of the Omaha Engineer District in the summer of 1961.[11] Tom James, a civilian engineer assigned to the demil operations, recalled that the plant had to be closed in either 1982 or 1983 because of safety problems that could not be corrected. These problems had been found in an Occupational Health and Safety inspection.[12]

## BIOLOGICAL WEAPONS (1964-1973)

The United States biological-warfare research program started with efforts by the CWS in 1941. The program was greatly expanded in 1942 when Secretary of War Henry Stimson approved a report of the National Academy of Sciences and established a high-level "germ warfare" advisory group working covertly in the Federal Security Agency. Headed by George W. Merck, president of the pharmaceutical firm Merck & Company, this group was subsequently known as the War Research Service (WRS) and directed secret contract work with American universities. Diseases such as anthrax and botulism, caused by spore-forming bacteria, were the foci of their efforts during the war years. The WRS also directed the work of the CWS and authorized them to build research facilities,

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[11]*RMA History*, Volume 39, pages 32-35; "1960s," *Eagle Watch: Special Historical Issue*, Volume 4, Issue 8 (August 1992), page 10; John F. Lauber and Jeffrey A. Hess, "Historic American Engineering Record: Glenn L. Martin, Titan Missle Testing Facilities (Martin Marietta Missile Testing Facilities) HAER Number CO-75" (Denver, Colorado: U.S. Department of the Interior, National Park Service, December 1993), pages 56-63, on file at the Historic American Engineering Record collection, Library of Congress, Washington, D.C.

[12]Tom James to the author, April 19, 1996.

most notably Camp Detrick in Frederick, Maryland (subsequently renamed Fort Detrick) and hire a number of academic scientists then working on aspects of biological warfare (BW). By the end of the war the CWS had succeeded in developing anthrax and botulism toxic bombs. Merck also reported to Secretary Stimson in late 1944 research in bacterias including brucellosis (undulant fever), psittacosis (parrot fever), tularemia (rabbit fever) and the respiratory disease glanders as well as the development of at least five agents used to destroy food-crop plants.[13]

At the end of World War II, the BW program was being managed by the Department of the Army under the direction of the Chief Chemical Officer. The work was coordinated from Camp Detrick and was confined to contracts with universities and industry on "BW agent research and defensive aspects; some applied research on dissemination devices; the collation and digestion of the large scale R&D effort carried out during World War II; and the formation of sound research and development program frameworks."[14] In the summer of 1953, a BW production plant was completed at Pine Bluff Arsenal. Within two years the plant produced a subtype of brucellosis (commonly known as undulant fever), *Brucella suis*, an infectious, bacterial

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[13]Barton Bernstein, *Origins of the Biological Warfare Program*, IN Susan Wright, ed., *Preventing a Biological Arms Race* (Cambridge, Massachusetts: The MIT Press, 1990), pages 9-15.

[14]Department of the Army, "U.S. Army Activity in the U.S.Biological Warfare Programs," Volume I, February 15, 1977, microfilm (RSA 019), frames 0009-0010, on file at the Technical Information Library, Rocky Mountain Arsenal, Commerce City, Colorado (hereinafter cited as "Biological Warfare Programs").

disease found in swine. The Pine Bluff plant also developed a subtype of tularemia (commonly known as rabbit fever), *Pasturella tularensis*, an infectious, bacterial disease found in rabbits, squirrels, rats, fleas, and ticks.[15]

Fort Dietrick, Maryland managed projects that developed anticrop agents in the 1950s; this work was continued and, in fact, accelerated in the 1960s during the Vietnam War Years. Three agents were developed--stem rust of wheat, rye, and rice blast, designed for defoliation or crop destruction. Between 1951 and 1957, wheat stem rust spores and rye stem rust spores were produced from inoculated crops at government planting sites. Wheat rust spores were transferred to RMA and some were placed in cold storage, while others were planted in Sections 23, 24, 25, and 26 in tbe buffer zone north of South Plants, near North Plants. The project started about 1964 and ended in 1968. The existing stockpile of spores were destroyed by February 1973. The United States terminated its BW program in 1969, in response to growing international pressure to ban use of these agents.[16]

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[15]Ibid., frame 0019; Compton, *Military Chemical and Biological Agents*, pages 363, 374.

[16]Biological Warfare Programs, frames 0028, 0033, 0081-0083; Kuznear and, "History of Pollution Sources and Hazards at Rocky Mountain Arsenal,"page 58.

## DEMILITARIZATION OF CHEMICAL WEAPONS

After the end of the Korean War and completion of the Sarin program requirements in the mid-1950, the Arsenal reduced its operations to a minimum. Plant buildings and equipment were minimally maintained or, at South Plants, leased to Shell Chemical Company. A lined basin used for the disposal of waste products from various waste chemicals was constructed in 1956. The Arsenal remained in its standby status until the 1980s, when legislation was passed mandating the destruction of chemical weapons, work that would be assigned to it.

Pursuant to the Department of Defense Appropriation Act of 1986, the Secretary of Defense was directed to destroy the current chemical weapons stockpile in a safe and effective manner. This decision was prompted because of the military's planned acquisition of newer binary weapons; a decision that was never fully implemented. This task was delegated to the Department of the Army and in turn to the Chemical Warfare Service. The chemicals involved included crude mustard, distilled mustard and nerve agent filled containers and munitions then stored at RMA and elsewhere. The military had first proposed to transport the material across country and dump it at deep water sites, a disposal procedure used safely since World War I and known as Operation CHASE (Cut Hole and Sink em). But public fears regarding the transportation of agents across the country fueled, in part, by the deaths of thousands of sheep from the nerve agent VX in 1968 at Skull Valley near Dugway, Utah, combined with concerns about environmental effects forced the government to evaluate this procedure. The

Army commissioned an expert panel from the National Academy of Sciences to study CHASE. The commission vigorously opposed ocean dumping and recommended instead incineration of the mustard--H and HD--and chemical neutralization of the nerve agent GB.[17] [See HAER No. CO-21 drawing 6 of 13 "Demilitarization: South Plants, 1947-1974."]

## PROJECT EAGLE--PHASE I (MUSTARD) (1972-1974)

Mustard was incinerated first and the activity, designated Project Eagle--Phase I,was initiated in August 1972. By February 1974, 6.14 million pounds had been decontaminated. The one-ton containers were heated to liquify the mustard, cut open, and the chemical agent was destroyed at high temperature in the modified hydrazine furnace or used to burn contaminated liquid hydrazine. The one-ton containers were thermally decontaminated in an adjacent furnace, built in 1944 for the processing of fifty-five-gallon drums of mustard.[18]

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[17]Jerry Melito and William Moloney, eds., "Final Report, Project Eagle, Phase II, Demilitarization and Disposal of the M34 GB Cluster at Rocky Mountain Arsenal" (Commerce City, Colorado: Rocky Mountain Arsenal, January 30, 1978), page 2-1;Robert Harris and Jeremy Paxman, *A Higher Form of Killing: The Secret Story of Gas and Germ Warfare* (London, England: Chatto & Windus, 1982), page 216; U.S. Army Toxic and Hazardous materials Agency, "Chemical Stockpile Disposal Program," (Aberdeen Proving Ground, Maryland: U.S. Army Toxic andHazardous Materials Agency, 1986?), page 4; U.S. Congress, Office of Technology Assessment, *Disposal of Chemical Weapons: Alternative Technologies-Background Paper*, OTA-BP-O-95 (Washington, D.C.: Government Printing Office, June 1992), page 1.

[18]Kevin J. Flamm, Quon Kwan, and William B. McNulty, "Chemical Agent and Munitions Disposal: Summary of the U.S. Army's Experience" (Aberdeen Proving Ground,

PROJECT EAGLE--PHASE II (STORED SARIN) (1974)

The stored nerve agent GB, as well as munitions filled with nerve agent, was neutralized and "demilled". Project Eagle -- Phase II (Expanded) was initiated in September 1974 for the purpose of destroying the existing supply of GB held in the underground storage tanks at RMA [See HAER No. CO-21 drawing 8 of 13 "Demilitarization: GB (Sarin) Nerve Agent"]. The GB was pumped from underground storage tanks in Building 1506 into neutralization reactors installed in Building 1601. The reactors were filled with a caustic solution of sodium hydroxide (NAOH), stored in a ten-thousand-gallon tank on the roof of 1601. The solution was continuously recirculated in the reactors until neutralization had been confirmed. The brine solution was pumped to Building 1703, where a spray dryer was installed. In the spray dryer, the brine solution was mixed with heated air, reducing it to salt. The water in the mixture was evaporated during this operation.

The salts, water vapor, and heated air were then forced through four cyclone separators and the heavier dried salt particles dropped into hoppers. The heated air and water vapor passed through system designed to remove contaminated particulates before release of the gases through the 100-foot stack into the atmosphere. The dried salts were sealed in corrosion resistant, epoxyphenolic line fifty-five gallon drums, since this

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Maryland: Program Executive Officer -- Program Manager for Chemical Demilitarization, September 21, 1987), pages 1-9-10, 4-5, 4-12. On August 24, 1960, RMA began construction of a missil fuel blending plant designed to blend hydrazine and unsymmetrical dimethyl hydrazine as fuel for Air Force missiles. *RMA History*, Volume 39, page 32.

was still a hazardous waste. The sealed drums were sent to Grassie Mountain, Utah around 1985. By November 1974, some 378,000 pounds of GB had been neutralized.[19]

## M34 CLUSTERS FILLED WITH GB (1973-1976)

Nerve agent munitions were destroyed as well during this time. Work on the M34 clusters started in October 1973, in Building 1606, specially modified for this project. The clusters were transported from the Toxic Storage Yard to 1606 [See HAER No. CO-21-DE], where they were disassembled in explosion-proof cubicles. The seventy-six individual bombs (M-125) were removed and the casings were punctured at a designated station along the automated Zig-Zag conveyor. The GB was allowed to drain through an enclosed line into a holding tank in 1606 and periodically pumped into the main storage tank of 1601 for subsequent neutralization. The casing went through a caustic dipping tank and then the burster well was sheared at the fuze. The casing then proceeded into the deactivation furnace and finally passed through the decontamination furnace where it remained for about twenty-five minutes at a temperature of 1,500 degrees Farenheit. By the middle of September 1976, over twenty-one thousand clusters had been demilled.[20]

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[19]Flamm, et al., "Chemical Agent and Munitions Disposal", pages 1-4, 3-16, 3-20-21; Tom James to the author, April 18, 1996. Mr. James, now a Senior Engineer (Operations), was a civilian engineer employed at RMA during this time and working on demil.

[20]Melito and Moloney, eds., "Project Eagle Phase II, Demilitarization . . . of the M34", pages 3-1, 3-3, 3-9-3-15, 5-3; Tom G. James to the author, April 18, 1996.

## DEMIL OF WETEYE BOMBS (1976)

The demil of Weteye bombs, a modified Navy munitions, was started, also. The project was a continuation of Project Eagle and bombs were deactivated in Building 1601A. The work consisted of the following major elements:

1. Transport from toxic storage yard to Building 1601A;
2. Handling and stripping the bombs of external hardware (tail fin assembly, suspension assembly, and counterweight assembly);
3. Punching, draining, and rinsing the casings;
4. Transfer of product from measuring tank to underground storage tank (1606);
5. Thermal decontamination of casings.[21]

Upon completion in late 1976, some 311,750 pounds (34,490 gallons) of nerve agent had been neutralized and 901 Weteye bombs had been destroyed.[22] The remaining 880 Weteye GB filled bombs were transported by air from RMA to Tooele Army Depot, Utah, in August 1981.[23]

## DEMIL OF HONEST JOHN M190 WARHEAD (1976)

Another weapon that was demilLed at this time was the Honest John M190 Warhead and M 139 bomblet (then stored in thirty-gallon drums). Building 1611 was repartitioned

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[21]Captain David L. Daughdrill, "Expanded Project Eagle, Disposal of GB in Weteye Bombs at Rocky Mountain Arsenal, July 1975" (Aberdeen Proving Ground, Maryland: U.S. Army, Chemical Corps, Office of the Program Manager for Demilitarization of Chemical Materiel, 1975), pages 1-5.

[22]Ibid., page 2.

[23]"Chapter 12, History, Rocky Mountain Arsenal, Program Manager, Rocky Mountain Arsenal," undated, copy on file at the Technical Information Center, Rocky Mountain Arsenal, Commerce City, Colorado, page 12-2.

and refitted for this project. The work started in April 1976 and the process of deactivating the bomb was similar to the other demil operations. The GB was removed in a punch operation and drained into holding tanks where it was pumped to Building 1606. The casing was finally processed in a deactivating furnace and thermally decontaminated. The project was completed in November 1976 and about 78,000 pounds of GB were neutralized, and 106 M190 Warheads (with 368 bomblets each), 1,222 M139 bomblets, and 39,532 M139 bomblet halves were destroyed.[24] In total some 4,188 tons of GB and 3,071 tons of crude and distilled mustard were neutralized or incinerated between 1973 and 1976.[25]

## CHEMICAL IDENTIFICATION SETS (1979-1982)

In the early eighties, the Army's stockpile of obsolete chemical agent identification sets were destroyed, as well, in an effort known as the Chemical Agent Identification Set (CAIS) Disposal Program. Chemical agent identification sets contained sample amounts of various agents--Mustard, Lewisite, Phosgene, and Sarin-- and were used to train soldiers in smell recognition. The Department of the Army declared the CAISs obsolete

[24]Samuel W. Hasson, Jr., "Expanded Project Eagle, Demilitarization and Disposal of the M190 Warhead/M139 Bomblet at Rocky Mountain Arsenal, September 1975" (Aberdeen Proving Ground, Maryland: U.S. Army, Chemical Corps, Office of the Project Manager for Chemical Demilitarization and Installation Restoration,, 1975), page 1-3, D1-1.

[25]Donald L Siebenaler, Study Director, et al., *Alternative Technologies for the Destruction of Chemical Agents and Munitions* (Washington, D.C.: National Academy Press, 1993), pages 55-56.

in April 1971; the sets were subsequently transferred to RMA in two separate operations called Set Consolidation (SETCON) I (1978) and SETCON II (1980). RMA conducted a pilot program which destroyed, by incineration, 1761 sets in the fall of 1979. The actual disposal program was conducted in three phases, which took place between May 1981 and December 1982, and on completion some 19,697 sets had been successfully decontaminated.[26] The work was carried out in 1611, since this building already had the incineration equipment.[27]

[26]Flamm, et al., "Chemical Agent and Munitions Disposal", page 1-4, 4-27-4-32.

[27]Tom James to the author, April 19, 1996.

## THE BAN ON BIOLOGICAL AND CHEMICAL WEAPONS (1969-1997)

The United States's policy toward biological weapons changed radically in 1969 when President Richard Nixon announced that America would no longer develop, produce, and stockpile biological weapons. He also ordered that our existing supply of these weapons was to be destroyed. This policy was extended in 1970 to include toxin weapons, as well. Internationally, the United States and the Soviet Union signed the Biological Weapons Convention which became part of international law in 1975. Also in the 1970s negotiation on the development of a treaty prohibiting chemical weapons were initiated between the Americans and the Soviets. The treaty, known as the Chemical Weapons Convention, was finalized in 1992, endorsed by the United Nations, and opened for signature in Paris in January 1993. As of the spring of 1997, the United States has not ratified the treaty, but prospects for favorable consideration by the U.S. Congress appear good.

Following a high level policy meeting between President Ronald Reagan and Mikhail Gorbachev, First Secretary of the Communist Party, in November 1985, the Soviets agreed to American demands for a chemical weapons convention, to open one of their chemical plants for inspection, and to provide details about an anthrax epidemic. This breakthrough was followed in 1986-1987 when the two superpowers agreed to several highly intrusive verification measures including the declaration of the location and inventories of all chemical weapons stockpiles, verification of the destruction of these stockpiles, and "challenge" inspections at short notice and without right of refusal. Rocky

Mountain Arsenal is included in this agreement and the United States government is working with the Russians to ensure full compliance.[28]

[28]Susan Wright, "Evolution of Biological Warfare Policy: 1945-1990," IN Wright, *Preventing a Biological Arms Race*, pages 39, 41, 55-57; Barend ter Haar, *The Future of Biological Weapons* (New York, New York: Praeger, 1991), pages 1-53; Brad Roberts and H. Martin Lancaster, *Ratifying the Chemical Weapons Convention* (Washington, D.C.: The Center for Strategic & International Studies, 1994), 1-10, 110-114.

CLEANUP (1956-1996)

The waste products from chemical manufacturing at RMA--including Shell Chemical Company operations-- were eventually allowed to drain into natural basins, following generally accepted practices at the time. In response to complaints from residents of Adams County about contaminated groundwater, in 1956, the Army constructed its first lined basin, "F", a ninety-three-acre asphalt-lined storage pond built primarily for the storage of liquid wastes from GB production. The asphalt liner was supposed to function so that there would no longer be any opportunity for the liquid wastes to contaminate the soil and water. It was expected that the liquid would slowly evaporate and the remaining solid material would be disposed of in some manner. Concern about contaminated ground water migration to adjacent community water systems intensified over the decades and by the 1970s the Colorado Health Department ordered the Army and Shell to stop polluting the water.

By the early 1980s the principals--including the Department of the Army, the Environmental Protection Agency, the State of Colorado, and Shell Oil Company--found their differences irreconcilable and filed suit against each other in Federal district court. In 1988, an interim Consent Decree was signed by all parties, except by the State of Colorado, which defined their roles in cleanup as well as assigning costs. The Consent Decree stated that all work at RMA would be done in accordance with the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Cleanup is also being done in conformance with the Federal Facility

Agreement of 1989, which the State has not signed as well. Besides controlling ground water migration and collecting and analyzing data, a clean up strategy was selected for Basin F. Here it was decided to use a high-temperature incineration process to treat the approximately eleven million gallons of waste liquid. A state-of-the-art facility, known as a Submerged Quench Incinerator developed by T-Thermal, Inc. of Conshohocken, Pennsylvania, was constructed in 1991 and started operations on 1993. All of the contaminated liquid had been treated by May 1995. The innnovative plant was officially decommissioned on July 6, 1995, and sold to Midwest Steel in September 1995.[29]

The Off-Post Record of Decision (ROD) was signed by all parties on December 19, 1995. The agreement includes continuation of the OffPost Groundwater Intercept and Treatment System, a process technology that captures groundwater along RMA's northern boundary and then treats it to remove contaminants before the water is re-introduced into the system. The Off-Post ROD also ensures that residents of Adams County, Colorado will have safe drinking water. A final settlement for on-post clean up was reached in 1996 and the Record of Decision was signed on June 11, 1996, prescribing multiple remedies depending on the medium--soil, water, air, biota, and buildings--involved. The U. S. Department of the Army and Shell Oil Company (the parent company of Shell Chemical Company) have agreed to pay 2.2 billion dollars for

[29]*Eagle Watch*, Volume 7, Issue 14, July 17, 1995, page 1; Volume 7, Issue 18, September 18, 1995, page 1.

the required cleanup over the next ten years.[30] [See HAER No. CO-21 drawing 9 of 13 "Production End, 1982" and 10 of 13 "Containment/Cleanup, 1995."]

The future of RMA has been decided, as well. Once the cleanup has been completed, 17,000 acres will be designated as a wildlife refuge, in accordance with the Rocky Mountain Arsenal Wildlife Refuge Act of 1992 (RMAWRA). This decision resulted from the 1986 sightings of numbers of bald eagles wintering at RMA along with resident populations of over three hundred other species of fish and wildlife. To protect these species, the U.S. Department of the Army and the U.S. Fish and Wildlife Services (USFWS) negotiated a series of agreements to manage the fish and wildlife. Since 1993, the USFWS has managed the facility relating to wildlife and public use. In fulfilling its mission to manage the Arsenal's wildlife, the USFWS has undertaken numerous studies to ensure that resident populations or migratory bird species are not adversely affected by contaminants in the soil, water, or air.

The Federal Facility Agreement recognized the public use mission of the USFWS, stating, "'It is the goal of the Organizations that, following certification of completion of the Final Response Action for the On-Post Operable Unit, significant portions of the Arsenal will be available for open space for public benefit (including, but not limited to, wildlife habitat(s) and park(s)) consistent with the terms of this Agreement.'" In accordance with the RMAWRA, the Arsenal is currently being managed by the U. S

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[30]Ibid., Volume 8, Issue 1, January 5, 1996, page 1; Volume 8, Issue 12, June 21, 1996, page 1.

Fish and Wildlife Service as if it were a unit of the National Wildlife Refuge System (NWRS). After cleanup is finished, the Arsenal will become a permanent unit of the NWRS.[31] [See HAER No. CO-21 drawing 13 of 13 "Arsenal Future."]

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[31]Division of Interpretation, National Park Service, Rocky Mountain Region [now Intermountain Field Area], *A Plan for the Interpretation of The Rocky Mountain Arsenal National Wildlife Refuge, Commerce City, Colorado* (Denver, Colorado: Rocky Mountain Region, National Park Service, November 1994), page 18, copy on file at the Rocky Mountain System Support Office, Intermountain Field Area, National Park Service, Denver, Colorado.

## SUMMARY -- SIGNIFICANCE STATEMENT

Rocky Mountain Arsenal is internationally significant for its role in chemical weapons technology, particularly as the only manufacturing facility for the nerve agent Sarin outside of the former Soviet Union. Like other chemical weapons, Sarin was never used in combat, but was part of our deterrent strategy. The Arsenal was built in the early years of World War II as a chemical weapons manufacturing facility. Before the end of the war, Arsenal workers, including women, had produced distilled mustard, Lewisite, and incendiary bombs--M47s and M74s. These incendiary bombs were used effectively against both the Germans and the Japanese. Rocky Mountain Arsenal played a major role in the immediate postwar demilitarization of chemical weapons as well as more recent operations to destroy mustard- and Sarin-filled munitions. The Arsenal was also used in biological agents research before the ban on these weapons. And finally, the Denver site was used to produce the new fuel mixture needed for the intercontinental ballistic missile, Titan II. Equipped with nuclear warheads, Titan II missiles were employed at military installations in the midwest and west from the 1960s until they were replaced by the Minuteman missiles in the 1980s. The fuel blended at the Denver facility was used also to power the Titan rockets employed in the space program.

But Rocky Mountain Arsenal is nationally significant, as well, because of the decades-long controversy over contamination that has influenced the discussion of hazardous materials and their impacts on communities well beyond the region. It had been designated as a Superfund site under the Comprehensive Environmental Response, Compensation and Liability Act and is known to many Americans as the "most polluted square mile in America." This supposed high-level of contamination influenced the decision not to expand the former Stapleton Airport, built in 1929, which was located just south of the Arsenal and convinced the public and congressional leaders that a new airport had to be built in another location. In response to unique cleanup problems much new and innovative technology was developed there which can be used at other sites. Rocky Mountain Arsenal is significant also as a wildlife habitat and refuge, particularly for bald eagles, and as a partially isolated ecosystem in proximity to an urban area.

# PART II: TECHNICAL PROCESSES

NOTE: All of the descriptions of the chemical manufacturing processes have been extensively reviewed by military personnel for security purposes.

## CHEMICAL AGENT PRODUCTION:

### MUSTARD (1942-1945):

#### BACKGROUND (Pre-1942)

The Chemical Manufacturing and Filling Area Plants were among the first facilities constructed at RMA. Mustard, of course, was the most important chemical agent manufactured at RMA during World War II.[1] It was developed early in the nineteenth century, but it was not until Victor Meyer's work late in the century that a much purer product was obtained by chlorinating thiodigiglycol. His work was resurrected thirty years later by German scientists searching for new chemical warfare agents.[2] Crude mustard (H) is a mixture of approximately seventy percent B,B'-dichloroethyl sulfide and thirty percent of sulphur and other sulphur compounds. The United States used the Levinstein process developed by the English in which ethylene reacted with sulphur monochloride under carefully controlled conditions.[3] The reaction dynamics proved

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[1]Mustard gas's official chemical designation is dichlorodiethyl sulphide.

[2]Jan Medema, "Mustard Gas: The Science of H," *NBC Defense & Technology International*, Volume 1, Number 4, pages 66-67; M. Gomberg, "Ethylene Chlorohydrin and B,B-Dichloroethyl-Sulfide," *Journal of the American Chemical Society*, Volume 41 (1919), page 1414.

[3]James K. Senior, "The Manufacture of Mustard Gas in World War I," *Armed Forces Chemical Journal*, 12 (September-October 1958), pages 12-14, 16-17, 29; 12 (November-December 1958), pages 26-29; Frederick George Mann and William Jackson Pope,

difficult to control and continued to be so through the beginning of World War II, much to the consternation of CWS chemists. Beyond this major technical problem, however, the Levinstein process resulted in a very impure product. The impurity reduced the effectiveness of the product and, also, made long-term storage risky. The NRDC attempted to improve the Levinstein process and coordinated multiple research contracts with the University of Illinois, Harvard University, and the Chemical Department of E. I. Du Pont de Nemours and Company. But by 1942, the work was terminated when it failed to show substantive progress and ultimately the solution was found in other process technology.[4]

## ETHYLENE AND SULPHUR MONOCHLORIDE (1942-1945)

The chemicals, ethylene and sulphur monochloride, used to produce mustard were manufactured at RMA. The Sulphur Monochloride (SM) Plant consisted of the Manufacturing Building, 411, [See HAER No. CO-21-AC] and a series of storage tanks--411A to 411J. Equipment consisted of mechanical means to move the raw sulfur--which was received by rail in bulk--from storage piles into eight-foot by twelve-foot weigh tanks and then into specially constructed all-welded, steel "batch" reactor tanks.[5] A seed

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"Production and Reaction of B,B'-Dichlorodiethyl Sulphide," *Journal of the Chemical Society*, Volume 121 (1922), page 594.

[4]Noyes, *Chemistry*, pages 162-166.

[5]*RMA History*, Volume 8, pages 2496-2497. The weigh tanks were manufactured by Stearns-Rogers Manufacturing Company, Denver; the reactor tanks were produced by Eaton Metal Products Company, Denver. In a "batch" process, the reactants are added to the

charge of SM was left in the reactor vessels to enhance reaction, which started when chlorine was fed into the tanks. Specific gravity readings of samples were taken and when the gravity of pure SM was reached, the reaction was stopped by shutting off the chlorine flow. Sulphur Dichloride (SD) was produced in one of the reactors through the same process and the product was established by testing for its specific gravity. The liquid SM or SD was pumped from the reactors to other manufacturing plants or piped to bulk storage tanks.[6]

The other chemical needed to produce Levinstein mustard was ethylene gas. The Ethylene Manufacturing Plant included alcohol storage tanks of welded steel, Buildings 463A to 463H [See HAER No. CO-21-M] and an ethylene generation building--433 [See HAER No. CO-21-D]. The process involved the catalytic dehydration of ethyl alcohol under controlled temperature conditions. The alcohol was piped by gravity from the storage tanks through steam-heated vaporizers into generators, where it contacted

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reactor at the beginning of the reaction; the reaction proceeds, and the compositions change over time. The reaction is stopped and the product withdrawn when the required conversion has been reached. The reactor is the focal point of a chemical process. It is the only place in the process where raw materials are converted into products.

[6]*RMA History*, Volume 8, pages 2496-2501. The bulk storage tanks were ten feet in diameter and twenty-eight feet long, with a capacity of sixteen thousand three hundred and thirty gallons. They were made of welded steel construction and manufactured by Eaton Metal Products Company, Denver. Specific gravity is a ratio of the mass of a solid or liquid to the mass of an equal volume of distilled water. The specific gravity for SM is 1.2741@ twenty degrees Centigrade. F. Feher, "Dichloromonosulfane" [Sulfur Dichloride], "Dichlorodusulfane" [Sulfur Monochloride], in Georg Brauer, ed., *Handbook of Preparative Inorganic Chemistry*, 2 Volumes (New York, New York: Academic Press, 1963), Volume 1, pages 370-372.

aluminum oxide catalysts and was converted into ethylene. The finished gas was pumped under pressure into one of two gas holders, constructed of steel shell, steel frame, and concrete water-seal tank. Each tank had a capacity of 300,000 cubic feet.[7]

## LEVINSTEIN MUSTARD PLANT (1942-1945)

The Levinstein mustard plant was built in proximity to the SM and ethylene generation plants and the three plants formed the H manufacturing facility.[8] [See HAER No. CO-21 drawing 3 of 13 "Chemical Production: Crude Mustard and Lewisite."] This layout differed from other mustard plants in the United States that were based on a "unit" design. The RMA plan supposedly resulted in savings of equipment: H reactors, ethylene generating units, and SM reactors. The RMA H Plant was based, though, on standard CWS drawings, refined by Whitman, Requardt & Smith and H. A. Kuljian & Company. The construction was jointly supervised by Kershaw, Swinerton & Walberg and the Corps of Engineers. The first batch of H was completed in the evening of December 31, 1942, barely meeting the deadline. The H Plant was designed to produce 150 tons of H during every twenty-four hour cycle.[9]

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[7]*RMA History*, Volume 2, part 2, pages 581-585.

[8]H was the CWS symbol for the Levinstein mustard process. "H" was supposedly based a reference to Hun, a term used by Allied soldiers in World War I.

[9]*RMA History*, Volume 8, pages 2508-2509. All of the design specifications, process drawings, and formulae for chemical agents manufactured at RMA are located in the "classified vault," Rocky Mountain Arsenal. These sources are currently classified "secret." None of this information and data is being cited or indirectly referenced in this document.

Mustard was manufactured in both Building 412 and 422 [See HAER No. CO-21-B and CO-21-AG], which were identical. The constituent intermediates were mixed in Struthers Wells reactors, which were nearly six feet in diameter (inside) and ten feet high, with input and output piping connections. Inside each "stirred tank" reactor there was a seven-spoke agitator powered by a thirty-horse-power General Electric explosion-proof motor and a set of brine coils.[10] A seed charge of H remained in each reactor to start the reaction. Attached to each reactor was a twenty-five-gallon measuring bottle filled with SM. The SM was slowly added to the reactor simulanteously with the ethylene and the temperature of the mix was maintained at between thirty to thirty-four degrees Centigrade.[11] Control of the exothermic reaction was achieved by circulating brine reactor jackets and coils, along with continuous agitation of the mix. Unabsorbed ethylene--sometimes referred to as tail gas--was vented to the caustic scrubber.

[10]Reactor design can be classified into the following broad categories: 1) Stirred Tank Reactors. These reactors consist of a tank fitted with a mechanical agitator and cooling jacket or coils; 2) Tubular Reactors. These reactors are usually used for gaseous reactions, but are also sometimes employed in liquid-phase reactions; 3) Packed-bed Reactors. There are two basic types of packed-bed reactors: those in which the solid is a reactant, and those in which the solid is a catalyst; and Fluidised-bed reactors. In these reactors the solids are held in suspension by the upward flow of the reacting fluid to promote high mass and heat-transfer rates and good mixing. J. Mm Coulson and J. F. Richardson, *Chemical Engineering*, Volume 6, *An Introduction to Chemical Engineering Design* (New York, New York: Pergamon Press, 1983), page 384.

[11]This process was known as the "30 C process." An alternate process maintained the temperature at about 55 to 60 degrees centigrade and was thus known as the "60 C process." The third process was known as the "French process." Marshall Gates and Stanford Moore, "Mustard Gas and Other Sulfur Mustards," *Chemical Warfare Agents and Related Chemical Problems*, Parts I-II (Washington, D.C.: Office of Scientific Research and Development, Division 9, 1946), pages 30-31.

Significant increases in the flow of tail gas indicated that the reaction was nearing completion, and samples were analyzed, the percentage of H being determined by titration. Finished batches were dumped into receiving tanks located in the pit of the storage section. Batches were held here until they had been analyzed by "CAL," the central analytical laboratory for RMA housed in Building 313 [HAER No. CO-21-AO].[12] Afterwards they were transferred to storage tanks, along with other accepted batches. Sump pumps mounted on each storage tank pumped the product into fifty-five-gallon drums or one-ton containers, which held 165 gallons.[13]

The H Manufacturing Plant was part of the Production Branch, Operations Division. Actual operation of the plant was done solely by civilian workers, under the supervision of the military. Shifting production quotas resulted in fluctuations in the labor force. When the plant was operating at full capacity, 377 workers were needed, but only 135 people were required when H production was reduced to twenty-four tons daily.

Delayed equipment deliveries and the failure of supporting facilities to produce needed intermediates were among the problems that had to be resolved to meet production quotas. During January 1943, the first 300 tons of H was produced from the "East Half" (included buildings 412, 414, 415, 416, and 417 [See HAER No. CO-21-B]) of

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[12]*RMA History*, Volume 3, part 2, page 941.

[13]*Ibid*, Volume 8, pages 2524-2525. Titration is the method of determining the concentration of a substance in solution by adding to it a standard reagent of known concentration. Pumps are divided into two general types: 1) dynamic pumps, such as centrifugal pumps; and 2) positive displacement pumps, such as reciprocating and diaphragm pumps.

the plant. In April, the East Half was closed and the "West Half" (included buildings 422, 424, 425, 426, 427 [See HAER No. CO-21-AG]) was placed in operation and produced nearly 1,000 tons of finished product. The H Plant closed after a record production month in May of 1,222 tons. The total production of the H Plant was 3,231 tons.[14]

DISTILLATION (1942-1945)

The Levinstein process produced an impure mustard and so the CWS, assisted by the NRDC, explored a number of purification methods beginning in the early 1940s.[15] In late 1943, a serendipitous visit by CWS chemist Captain J.W. Eastes to the University of Illinois provided them with the process link that they needed. Eastes observed that the Illinois chemists had obtained a nearly pure B,B'-dichloroethyl sulfide through a process of washing that removed the salts and acids followed by distillation under pressure.[16] The CWS had known of the value of vacuum distillation since the 1920s but had not used it in conjunction with water washing.[17] The Technical Division of the

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[14]Ibid., pages 2533-2534, 2539.

[15]Anonymous, "Levinstein-H," in Office of Scientific Research and Development, National Defense Research Committee, Division 11, *Miscellaneous Chemical Engineering Problems*, Volume 2
(Washington, D.C.: National Defense Research Committee, 1946), page 53.

[16]Anonymous, Agents III (Vesicants), Volume 3, *History of Research and Development of the Chemical Warfare Service in World War II*, pages 80-81.

[17]Elford D. Streeter, "Continuous Vacuum Still for Mustard Gas," *Industrial and Engineering Chemistry*, Volume 11 (1919), pages 292-294; Mann and Pope, "Production and Reactions of B,B'-Dichlorodiethyl Sulphine," page 594.

CWS confirmed the initial process findings and also established that it was feasible with current equipment and machinery. A pilot plant, followed by a production facility, was constructed at Edgewood Arsenal and the process technology was transferred to Denver by 1945.[18]

The mustard distillation plant (HD) consisted of the HD-W [est] Filling Plant (Building 512, formerly the Lewisite Filling Plant [See HAER No. CO-21-BL]); the HD-W Distillation Plant (Building 514, Formerly the L Reactor Plant [See HAER No. CO-21-BM]); the Dowtherm Boiler Unit (Building 514A, formerly the L Storage Building); the Change House (Building 517, formerly the L Change House [See HAER No. CO-21-BO]); the HD-W Residue Burner (Building 528 [See HAER No. CO-21-BR]); Caustic Make-up (Building 529); Crude H Storage (Building 536); Thaw House (Building 537); HD-W Drum Disposal (Building 538[ See HAER No. CO-21-BU]); Compressor House (Building 538A); and the Electric Transformer Station (Building 539).[19] [See HAER No. CO-21 drawing 4 of 13 "Chemical Production: Distilled Mustard Gas and Incendiary Bomb Facilities" and also drawing 5 of 13 "South Plants-1945".]

The distillation process started with the delivery of crude agent. Crude H in either

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[18]Brophy, *Chemical Warfare Service: From Laboratory to Field*, page 64; Anonymous, "Draft History [Chemical Warfare Service] WWII," page 201, Undated [ca. 1945], Assistant Chief for Materiel, Technical Division, General Administrative Services, 1942-1945, History of World War II to Office Orders, Box 192, Record Group 175, Records of the Chemical Corps, National Archives and Records Center, Suitland, Maryland (hereinafter cited as "Draft History, Chemical Warfare Service).

[19]*RMA History*, Volume 8, page 2546.

fifty-five-gallon drums or one-ton containers was received by rail or truck at the Thaw House (Building 537). The Thaw House was divided into three single rooms which could be used simulanteously for heating the containers of H. The temperature in the rooms was increased to 150 degrees Fahrenheit and maintained for approximately eight hours. The H was then transferred by means of vacuum using a dip pipe through the bung hole of each drum to receiver tanks. The drums or containers still had about sixty to one hundred pounds of product remaining and they were sent to a drum disposal unit located in building 538 (HD-W Drum Disposal). There the drums and containers were decontaminated by incineration and then crushed and sold as low-grade scrap iron.[20]

Meanwhile, the crude H was piped by vacuum from the receiving tanks to storage tanks located in the Crude H Storage Building 536. There were six 20,000-gallon storage tanks in Building 536. After sampling and testing, the crude H was then pumped from these tanks into two 8,000-gallon working supply tanks located in the tank room section of the HD-W Distillation Plant (Building 514 [See HAER No. CO-21-BM]). As the material was pumped to these tanks, the de-mulsification agent, "Tret-O-Lite," was added by means of the chemical proportioning pump. The crude H was then pumped into three 300-gallon measuring tanks installed on the third floor of the building. A measured charge of 300 gallons of crude H was combined with 150 gallons of water in one of three 500-gallon, glass-lined reactors, equipped with motor-driven agitators. These units were modified from Pfaudler reactors formerly used for the final reaction in

[20]Ibid., pages 2552-2553.

L manufacture. The crude H and water mixture was then agitated. After the agitation stopped, the mixture separated and the heavier H formed the bottom layer. The wash water flowed by gravity to the decontamination pit built at the north end of the building. The H was piped into two 2,000-gallon, glass-lined receiver tanks installed in a pit on the first floor, where additional separation took place. Under continuous vacuum the washed H was then pumped into other tanks of similar design, fitted with special glass-lined spray domes, where it was dried by contact with dry air, jetted with the H through a spray nozzle. Prior to spraying, the H was preheated by passage through a shell and tube type heater which is of special design and fabricated of Hastelloy "B"--a corrosive-resistant metal.[21]

Following the drying operation the dried H was pumped through shell and tube type, Hastelloy "B" heat exchangers manufactured by the John Nooter Boiler Works, St. Louis, Missouri. In the heat exchangers the crude H was heated to within ten degrees Fahrenheit of the boiling point before being discharged into the "stills." There were five 500-gallon glass-lined vacuum stills. These stills required modification of the Pfaudler reactors, formerly used in Lewisite manufacture. Heat for distillation was supplied from a Dowtherm boiler unit which was installed in Building 514A. Heat control was maintained for each unit by five hot operating type Dowtherm pumps. These pumps circulated the Dowtherm through other Hastelloy "B" shell and tube type heat exchangers with Dowtherm vapor from the boiler unit as the prime heating medium. Five three-

[21]Ibid., pages 2554-2555.

point control "Celectray" temperature recorders and controllers, manufactured by the Tagliabue Instrument Company, recorded and controlled the temperature of the Dowtherm. These instruments, which were mounted on a central control panel for the plant, also recorded the temperature of the vapor on exit from the still to the stripping condensers.

Distillation was completed under a pressure of twenty-five to forty millimeters of Hg (Mercury) absolute, and distillation was stopped when the charge temperature reached approximately 160 degrees centigrade. Each still was equipped with a special vertical shell and tube-type stripping condenser fabricated of Hastelloy "B" and manufactured by the John Nooter Boiler Works. The upper end of the condenser connected with the main vacuum manifold leading to the steam jet ejectors. The heated vapors from the stills passed into the lower headers of the vertical stripping condensers and passed upward to the jacketed tubes where the purified H was condensed, returning to the lower header, and then through the cooler to the distillate receiving tanks.

The distilled HD-W was then pumped under vacuum into one of two agent receiving and storage tanks located in the tank room of Building 514. Following satisfactory analysis, the product was subsequently pumped into storage tanks installed in the Filling Building (512 [See HAER No. CO-21-BK]). The finished product was finally ready for transfer into ton containers and placed in long-term storage. The highly toxic distillate residue was disposed of by incineration in specially designed residual burning furnaces, and the combustion gases were vented into the atmosphere through a two-hundred foot brick stack.[22] The HD manufacturing plant commenced operations on July 5, 1945 with the capacity of manufacturing 66 tons of HD daily. By the end of the war the HD Manufacturing Plant had produced 1,037 tons of purified mustard.[23]

**LEWISITE (1942-1945)**

The other chemical agent manufactured at RMA during the war was Lewisite [dichloro (2-chlorovinyl) arsine], a non-persistent arsenical developed by Winfred Lee Lewis and his team of researchers near the end of World War I. The Lewis process--partially based on the work of J. A. Niewland--was both complicated and dangerous, involving the reaction of acetylene with arsenic trichloride, in the presence of the catalyst aluminum chloride. This process resulted in a mixture of L-1 (2-chlorovinyldichloroarsine, Lewisite) with an optimum yield of twenty percent, L-2 (di-(2-chlorovinyl)-chloroarsine), L-3 (tris-(2-chlorovinyl)-arsine, and an explosive component.[24] Not only was the yield of Lewisite very low--about twenty percent--but the mixture also contained explosive material. Budgetary constraints forced the CWS to abandon further research on Lewisite during the inter-war years. Since the British were combatants earlier, they initiated further Lewisite process refinement in the later thirties.

[22]Ibid., pages 2551, 2555-2557.

[23]Ibid., page 2545.

[24]Lewis and Perkins, "Beta-Chlorovinyl Chloroarsines," page 290; Max Goldman and Jack C. Dacre, "Lewisite: Its Chemistry, Toxicology, and Biological Effects," *Reviews of Environmental Contamination and Toxicology*, Volume 110 (1989), page 77.

Before the end of the decade, they were able to produce a high grade product of Lewisite-1 at between eighty to eighty-five percent pure through the reaction of acetylene with arsenic trichloride in a hydrochloric acid solution with a mercuric chloride catalyst. Thionyl chloride was used also in the reaction for sludge removal. The corrosive nature of the catalytic solution prompted efforts to identify other catalysts, such as cuprous chloride, but these were not used at RMA.[25] A batch process, known as "M-1," using mercuric chloride with thionyl chloride, was employed at the Denver chemical agents facility.[26] [See HAER No. CO-21 drawing 3 of 13 "Chemical Production: Crude Mustard Gas and Lewisite-1942".]

## ARSENIC TRICHLORIDE (1942-1945)

The intermediates--thionyl chloride, acetylene, and arsenic trichloride--were all manufactured at specialized plants at the Arsenal. Arsenic trichloride (AT) was produced through the reaction of arsenic trioxide, shipped to the Denver facility, and sulphur monochloride (SM), manufactured on-site (see above) based on process refinements recently completed at the Pine Bluff Arsenal.[27] The AT plant design was

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[25]Marshall Gates, Jonathan W. Williams, and John A. Zapp, "Arsenicals," *Chemical Warfare Agents, and Related Chemical Problems*, Parts, I-II, pages 83-84; Noyes, *Chemistry*, page 159. Goldman and Dacre, "Lewisite: Its Chemistry," page 77.

[26]"Draft History, Chemical Warfare Service", pages 196-202; F. Wagenknecht and R. Juza, "Mercury (II) Amide Chloride," in Georg Brauer, ed., *Handbook of Preparative Inorganic Chemistry*, Volume 2, page 1114.

[27]Goldman and Dacre, "Lewisite", page 84; *RMA History*, Volume 8, pages 2681-2682; "Draft History, Chemical Warfare Service", pages 201-202; P. W. Schenk, "Diarsenic Trioxide," in Brauer, *Handbook of Preparative Inorganic Chemistry*, Volume 1, pages 600-601.

furnished by the Buffalo Foundry and Machine Company, Buffalo, New York, with a rated capacity of forty tons daily. It consisted of the AT Manufacturing Plant (Building 523), Arsenic Oxide Storage Silos (Buildings 523 C, D, E, F, and G [See HAER No. CO-21-E], AT Wet Storage Building (Building 523A), Auxiliary Sulfur Monochloride Manufacturing Building (523B), and Sulfur Dioxide Disposal Plant (Building 524).[28]

The first part of the reaction took place in eight 600-gallon reactor vessels, equipped with a 1,500-pound capacity weigh hopper for arsenic trioxide, a water-cooled primary condenser, and a refrigerated brine-cooled secondary condenser. Weigh tanks were connected to the reactors and provided SM. The reactors and auxiliary equipment were situated on the second floor of building 523. Arsenic trioxide was added to a charge of AT in the reactor, forming a slurry. After heating this mixture to a temperature of least 125 degrees Centigrade, SM manufactured at the nearby SM plant or recovered from the AT reactor sulfur sludge in the Auxiliary SM Manufacturing Building, was added. AT was distilled from the reaction mass and piped to four 1,600 gallon AT receiver tanks located on the first floor. At this point in the process, additional SM was added to react with any remaining arsenic trioxide. The finished product was piped to building 523A, where the product was stored in one of three 8,000-gallon storage tanks, and delivered on demand to the Lewisite Plant by means of blowcases (pumps), located below the

[28]*RMA History*, Volume 8, page 2665.

storage tanks.[29] The AT plant operated from April 1943 until shut-down seven months later. The total AT produced during this time amounted to 5,359,417 pounds.[30]

## THIONYL CHLORIDE (1942-1945)

Another of the chemicals, Thionyl chloride (TC), was manufactured locally and the plant consisted of the Reaction Building (471 [See HAER No. CO-21-BG]), Refrigeration Building (472 [See HAER No. CO-21-BH]), Drum Loading Building (473 [See HAER No. CO-21-BI]), and Car Warming shed (475). The plant design and production specifications were provided by Hooker Electrochemical Company of Niagara Falls, New York, who also consulted during the plant construction.[31] TC was produced in the Reaction Building and resulted from the reaction of sulfur dichloride, "oleum" (sulfuric acid), and chlorine.[32] The process took place in four discrete steps: 1) reaction; 2) distillation; 3) reworking of low grade material, and 4) blending.

The Reaction Building was equipped with ten 680-gallon reactors, each of which consisted of a glass-lined tank with a bolted jacket with a coil for steam, water, and air.

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[29]Ibid., pages 2666-2669, 2681-2683, 2686.

[30]Ibid., page 2692.

[31] Thionyl Chloride Plants, August 17, 1942, Index Briefs, 1918-1942, Records of the Office of the Chief [Chemical Warfare Service], Plan thru Plant, Box 358, Record Group 175, Records of the Chemical Corps, National Archives and Records Center, Suitland, Maryland.

[32]F. Feher, "Thionyl Chloride," in Brauer, *Handbook of Preparative Inorganic Chemistry*, Volume 1, pages 382-383.

The jacket was used for monochlorbenzane refrigerant. Installed in connection with the reactors was one 10,000- gallon sulfur dichloride storage tank, two 8,000-gallon-oleum storage tanks, one 400-gallon sulfur dichloride weigh tank, and two 500-gallon intermediate receiving tanks. The process started with the charging of the reactor with 4,200 pounds of sulfur dichloride to which was added the catalyst--antimony trichloride. Then oleum amounting to 3,390 pounds was slowly added. The rising heat from the reaction was reduced by means of minus ten degree Centigrade monochlorbenzene which was circulated through the reactor jacket. It was imperative that the temperature of the mixture be closely controlled and not exceed twenty-five degrees Centigrade. Chlorine was added at the rate of 50 pounds per hour until a total of 700 pounds was reached. At this point in the process, the use of monochlorbenzene was stopped. Steam was passed into the jacket coil and the mixture was heated slowly until the reflux temperature of seventy-six degrees Centigrade @ 760 millimeters Hg (Mercury) was established. At that point, the crude TC was transferred by vacuum, into two intermediate storage tanks.[33]

The distillation and reworking stages were carried out in six 500-gallon kettles, each of which consisted of a glass-lined tank equipped with a pressure jacket. Besides the kettles, six lead-lined air blowers, four 650-gallon finished product receiving tanks, one 1,800-gallon blending tank, and one 10,000-gallon finished product storage tank were

[33]RMA History, Volume 8, pages 2654-2655. Reflux involves the boiling of a liquids so that the vapors continuously condense for reboiling.

installed nearby in building 471. A charge of 400 gallons of crude TC was piped from the intermediate storage tanks to the kettles. The mixture was heated to the boiling point under pressure. Distillation occurred at a rate of approximately 18 gallons per hour. The first 100 gallons of distillate did not meet purity specifications and this "low grade cut" was collected in one of the receiving tanks for further reworking. The remaining 300 gallons constituted the "technical grade cut" and were sent into separate receiving tanks. In "reworking," 400 gallons of low grade cut were transferred back into the kettles and allowed to react with sulfur to which was added the catalyst--aluminum chloride. The charge again was heated to the boiling point and distilled over several hours. The reworking produced a high grade of TC which was transferred back to the receiving tanks. For the final step, the technical grade material was "blended" with high grade in the blending tank and mechanical agitation was used until the mixture produced a product that was at least 94 percent pure TC. The finished product was transferred to a storage tank and was then ready for use in Lewisite manufacture.[34] The TC plant operated between April and November 1943, producing 479.50 tons of product.[35]

## ACETYLENE (1942-1945)

The third major chemical used in Lewisite manufacture, acetylene was produced at RMA primarily in the Generation Building (522 [S ee HAER No. CO-21-BW]) and the

[34]Ibid., pages 2655-2656.

[35]Ibid., page 2647.

Acetylene Compression and Scrubbing Buildings (521 [See HAER No. CO-21-BP] and 525 [See HAER No. CO-21-BQ]). Also associated with the plant were two Acetylene Gas Holders (Buildings 518 and 519 See HAER No. CO-21-BY]) and a sulfuric acid storage tank (Building 522A). Acetylene resulted from the reaction of calcium carbide with water, with a lime by-product. Carbide, in 100- or 600-pound drums, was delivered to the site and loaded into hoppers installed in the Generation Building. Along with water, the carbide was fed into generators and the resultant gas was piped to the acetylene gas holders, with the lime sludge transferred either to the lime settling basins at the Lewisite Disposal Plant (Building 523) or the Sulfur Dioxide Disposal Plant (Building 524) for further use. Before the gas was sent to the Lewisite manufacturing plant, it was piped back into the Generation Building and was forced past three scrubber towers; the first two used sulfuric acid (to remove excess water) and the third, sodium hydroxide (to increase PH). The plant operated between April and November 1943, producing an estimated 28,000,000 cubic feet of acetylene.[36]

MANUFACTURE (1942-1945)

The manufacture, distillation, and storage of Lewisite (L) was done in two duplicate groups of structures: the east group included buildings 514 [See HAER No. CO-21-BM] (Manufacturing), 514A (Crude L Storage) , and 516 [See HAER No. CO-21-BP] (L Distillation); and the west group, buildings 511 [See HAER No. CO-21-BK]

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[36]Ibid., pages 2633-2666, 2641-2642.

(Manufacture), 511A (Crude L Storage), and 515 [See HAER No. CO-21-BJ] (L Distillation).[37] The initial batch operation was carried out in a steam-jacketed, glass-lined reactor, measuring five feet in diameter and five feet six inches in height. There were four reactors which were installed in each corner of the building. Connected with each bank of reactors was one 500 gallon, glass-lined catalyst storage tank, one 50 gallon glass-lined catalyst make-up tank, and one 360-gallon AT weigh tank, all located on the third floor of the Manufacturing building (514, 511). Each reactor, though, had a process control panel board used to both measure quantities as well as monitor the temperature and pressure of the batch during reaction. The catalyst mercuric chloride, AT, acetylene, and TC were added directly to the reactor from the respective storage tanks.[38] Steam, water, air, nitrogen, purge vent and other auxiliary piping were installed in systems of headers. Noxious gas by-products of the reactors were vented through the caustic air washer systems. Excess contaminated acetylene was vented through caustic scrubbing tower systems situated in each tank section.[39]

The crude L was piped to two 500-gallon, glass-lined crude L blowcases, which served two groups of reactors, and were located in a tank pit in the basement of the Manufacturing building. The crude product was then pumped into either six 2,000-gallon, glass-lined crude L storage tanks located in the north end of each tank room, or

[37]Ibid., Volume 3, part 2, page 773.

[38]Process details are still classified and will not be discussed in this report.

[39]*RMA History*, Volume 8, page 2595.

to the crude L "Lastiglas" lined storage tanks in buildings 511A or 514A. Lastiglas was the trade name for a synthetic coating specially applied by the Bishopric Products Company to steel tanks. The crude was subsequently pumped from here through blowcases to the crude L feed tanks in the L Distillation building.[40]

The Distillation building was equipped with two complete distillation units consisting of one degasser, with heating section; one steam-jet operated vacuum fractionating column; one inclined reboiler; two coolers and decanters, attached to decanting tanks; one barometric seal tank; one L receiving tank; and one finished L blowcase. Each unit was controlled by an individual panel board. The distillation units was equipped also with auxiliary components that include two steam jets with barometric seal leg; one main condenser for the fractionating column gases; one ammonia refrigerated vent condenser for gases from the main condenser with degasser; one caustic trap tank; one scrubbing tower; two caustic storage tanks; two caustic coolers for the scrubbing tower; two distillate coolers and two AT receivers from which AT was returned to the AT Wet Storage building.[41]

Crude L was transferred from the blowcases in the adjoining Manufacturing building into two 1,400-gallon crude feed storage tanks, six feet high and six feet in diameter, located on the third floor of the Distillation building. From the crude feed tanks the crude L was sent in sequence through the degasser, fractionating column, reboiler cooler

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[40]Ibid., page 2596-2597, 2607.

[41]Ibid., pages 2598-2599.

and decanter and barometric seal, to the finished L tank. The finished L was subsequently transferred to six 2,350 gallon storage tanks situated in the tank room of the L Filling building (512), where the product was placed in either ton containers or fifty-five-gallon drums.[42] The disposal of waste products from the L manufacturing, including the intermediates, was handled at the L Disposal building (513). The building was equipped with four disposal reactors, ten feet high and ten feet in diameter, constructed of reinforced glazed tile. Adjacent to the building were two waste settling basins, constructed on unlined earth dikes. These basins in turn drained into waste seepage ponds located north of the entire chemical plants area.[43]

The first batch of L was made in April 1943 and the original target was 23,067 tons. The plant, however, shut down permanently in November 1943, after producing only 4,553.5 tons. Production difficulties arose because the technical data from the pilot plant at Edgewood Arsenal was not accurate enough. The need to expedite the transition from pilot to production plant resulted in Edgewood ignoring problems with sludge and corrosion. These problems manifested themselves in Denver, causing production delays and damaged equipment. L Plant personnel were given minimal training and in order to compensate, production was gradually increased. The high corrosive rate of steel equipment caused periodic leaks and fumes of toxic materials. While gas masks were

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[42] Ibid., pages 2599-2600.

[43] Ibid., pages 2600-2601.

issued to everyone, many did not wear them, although visitors usually could not stand to stay in the buildings because of the fumes.[44]

## END OF PRODUCTION (1942-1945)

The CWS and their British counterparts had initiated intensive research on the effects of Lewisite by 1941 and their work confirmed that lethal doses of the product vapor could not be readily obtained in the field. The use of liquid Lewisite had only limited effectiveness and was far inferior to mustard. England, also, had developed an antidote, British Anti-Lewisite (2,3-dimercaptopropanol-1), which proved effective in neutralizing the effects of Lewisite.[45] The L Plant equipment was declared surplus and removed based on orders received from headquarters of the CWS. The East Crude L Manufacturing Plant and the L Filling Building were converted early in 1945 for H Distillation. The West Crude L Manufacturing Plant was converted at the same time for Chlorinated Paraffin Manufacture.[46]

## CHLORINE (1942-1945)

Although chlorine was not employed as a chemical agent, it was an essential component used in other toxic chemicals as well as smoke agents, protective ointment,

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[44]Ibid., pages 2593, 2620-2621.

[45]Gates, et al, "Arsenicals," pages 89, 94-95.

[46]*RMA History*, Volume 8, page 2593.

bleach, and other decontaminating substances. To meet the anticipated wartime demand, the CWS proposed to construct a 150-ton plant at Edgewood and established tentative working agreements with the chlorine industry. This figure was greatly exceeded, partially due to the needs of our allies. So in January 1942, the War Production Board advised the CWS that it should obtain chlorine from its own facilities. Chlorine plants were built at Edgewood, Huntsville, Pine Bluff, and Rocky Mountain Arsenal.[47]

Chlorine was produced at RMA through electrolysis of fused chlorides. The equipment needed to achieve this process consisted of a brine plant, cell room, liquefaction and purification unit, evaporation unit, and fusion unit. The Brine Treatment Plant included the raw brine plant (Building 247), brine treatment facilities (Building 248), and treated brine storage (Building 249). The Cell building (242 [See HAER No. CO-21-AJ]) was used for the installation of 400 Hooker Electrochemical Company Type "S" cells, arranged in eight rows of 50 each and the rectifier equipment--transformers, amplifiers, and rectifiers. To complete the liquefaction and purification required three separate operations in Building 243 [See HAER No. CO-21-AJ]: resaturation, purification, and liquefaction. The evaporation step was completed in Building 251, equipped with evaporator and salt recovery units. The disposal of the process by-product caustic is treated in the caustic fusion unit located in Buildings 254

[47]Brophy, Miles, and Cochrane, *The Chemical Warfare Service: from Laboratory to Field*, pages 271-272.

and 255 [See HAER No. CO-21-AX]. The principal equipment installed here included eleven 5000-gallon cast iron fusion pots and steel storage tanks, with piping. The Chlorine Plant commenced production on April 10, 1943 and continued operations until August 15, 1945. The total output of the plant was 31, 680 tons of chlorine.[48]

SARIN (1953-1957)

NORTH PLANTS

North Plants included the following buildings [see HAER No. CO-21 drawing 7 of 13 "Chemical Production: GB (Sarin) Nerve Agent Production and Filling."]:

1402 -- **Dichloro Tank Farm.** Consisted of twenty-four, 8,000 gallon, glass-lined, carbon steel tanks; constructed in August 1951.

1403 -- **Hydrogen Fluoride Storage** (referred to as "RA"). The RA tank storage consisted of two, 18,000-gallon, carbon- steel storage tanks, constructed in August 1951.

1404 -- **Carbon Tetrachloride Storage** (referred to as "WM"). One, 18,000 gallon carbon steel storage tank, constructed in August 1951. WM was used to wash-down Step-IV equipment.

1405 -- **Hydrochloric Acid Storage** (referred to as "FA"). FA storage consisted of two, 18,000 gallon, rubber-lined, carbon steel tanks, constructed in August 1951. FA was a by-produce of GB process.

1501 -- **Manufacturing Building** [See HAER No. CO-21-DB]

1502 -- **TB** [Isopropanol alcohol] **Storage Tanks and Unloading dock.** Consisted of a raised metal grating platform with metal grating catwalks that rotate at a horizontal position for access to the top of rail tank cars and six, 18,000 gallon storage tanks, constructed in August 1951.

[48] *RMA History*, Volume 8, 2436-2441; Volume 1, page 21.

1503 A, B, C -- **Scrubbers** [See HAER No. CO-21-DC]. Constructed in 1953 as part of the GB complex scrubber systems. The 1503 scrubbers were designed to neutralize residual toxic gases from the GB processing and storage facilities. The equipment included a sump pump, scrubber chamber, mist eliminator chamber, and an exhaust fan.

1504 -- **Stack.** 200-foot tall stack of steel on a reinforced concrete foundation which vented air from the GB plant building into the atmosphere after it passed through decontaminating scrubbers in the scrubber buildings, constructed in 1952.

1505 -- **Caustic** [Sodium Hydroxide] **Tank Farm.** Consisted of ten, 35,000 gallon, carbon steel tanks. Each tank had an inner glass liner, inner carbon steel liner, insulation liner, and an outer carbon steel liner, constructed in August 1951. The caustic was used for the detoxification of vent gases, neutralization of hydrochloric acid, and for the decontamination of various plant areas and equipment. Subsequent used as a neutralizing agent in the demilitarization process.

1506 -- **UY** [code name for Sarin] **Storage** [See HAER No. CO-21-DD]. Building 1506 was a reinforced concrete structure, consisting of ten underground vaults, each contained a 10,000 gallon storage tank, and five room above grade. The storage tanks were constructed of carbon steel. Two of the tanks had carbon steel centrifugal pumps used to pump GB from here to the filling machines. Construction was started in 1951 and completed in April 1953.

1507 -- **Methanol** [Methyl Alcohol] **Storage.** Consisted of a single, 18,000-gallon, carbon steel tank, constructed in August 1951. Methyl Alcohol was used for drying Step IV process equipment.

1508 -- **Tributylamine Storage Tank.** Consisted of a single, 10,000-gallon, carbon steel tank, constructed in August 1951. Tributylamine was used in the GB manufacturing process as a stabilizer.

1509 -- **Isopropanol Dehydration Unit.** This was a refinery structure that consisted of a 60 foot high steel tank. The tank equipment included dehydration column, calandria, heat exchangers, pumps and vessels all mounted on a concrete pad 30 feet square. The unit was designed to provide 8,000 gallons daily of 99% pure isopropanol. The dehydration was achieved from azeotropic distillation with ethyl ether. The unit was constructed in 1953.

1601 -- **Filling Building** [See HAER No. CO-21-DE]. Single-story structure of steel, with precast concrete roof. Completed in 1953.

1602 -- **Paint Storage Building** [See HAER No. CO-21-DJ]

1603A and B -- **Scrubber Facility.** Consisted of two, one-story steel frame structures, constructed in 1952. Used to clean the toxic gases vented from the munitions filling and assembly buildings [1501/1601] before the gases were released into the atmosphere through the 200-foot stack. Equipment included two exhaust ventilation scrubbers, divided into an upper and lower chamber. The lower chamber had an array of six panels of venturis with 1/2-inch spray nozzles. The upper chamber had seven mist eliminators. Additionally, each scrubber was equipped with a sump 24 by 8 by 3 feet deep.

1605 -- **Munitions Storage Igloo** [See HAER No. CO-21-DS]. Earth-covered reinforced concrete vault structure of about one thousand square feet, constructed in 1953.

1606 -- **Clustering Assembly Building** [See HAER No. CO-21-DE]. Single-story concrete structure, with shingle roof, constructed in August 1951, and used in the assembly of the M34 cluster bomb--M29 adapter and 76 M125 bombs. The M125s were filled in Building 1601 and transported to 1606 on a conveyor.

1607 -- **Warehouse.** One-story constructed of concrete blocks, with an insulated corrugated metal gable roof, built in either 1953 or 1954, for use as a general purpose warehouse.

1608 -- **Munitions Storage Igloo.** One-story earth covered chemical munitions storage igloo constructed of reinforced concrete floors, walls, and ceiling, of about 1,000 square feet. Constructed in 1953 and used for the storage of conventional munitions until 1982; after that date, chemical surety materials were stored there.

1609 -- **Munitions Storage Igloo.** Earth-covered reinforced concrete vault structure, constructed in 1953, and used as a storage magazine for conventional ammunition and explosives.

1610 -- **Munitions Storage Igloo.** Earth-covered reinforced concrete vault structure, constructed in 1953, and used for the storage of chemical surety material.

1611 -- **Tail Fin Storage and Assembly** [See HAER No. CO-21-DI]. Built in 1953 and used as an instrument shop and gymnasium. Subsequently converted for demil operations for the M190 and M139.

1613 -- **Explosive Unpacking Building** [See HAER No. CO-21-DK]. One-story, concrete block structure, built in 1953, and used to unpack fuze types: E10R1 and E24R1 as well as burster type E12R1. From 1613, the fuzes and bursters were transferred to Building 1606, for installation in GB cluster bombs.[49]

## MANUFACTURING IN BUILDING 1501 (1953-1955)

Agent manufacturing was completed in Building 1501 [See HAER NO. CO-21-DB, including drawing 1 of 1], a six-story, exposed concrete structure. There were three bays that could be operated separately or together to produce the nerve agent. The dichlor was pumped from storage tanks (1402), on demand from the operator of the central control panel (1501), into Hastelloy-"B" reactors, with attached Hastelloy-"B" stripper. There it reacted with hydrofluoric acid (1403). Further processing was done in a horizontal monel reactor condenser; vertical carbon steel reactor reboiler; vertical monel receiving and sampling tanks, with carbon steel jacket and monel agitator; vertical monel, 1,500-gallon, off-specification hold tank, with carbon steel jacket; and a vertical monel blend tank, with carbon steel jacket and monel agitator. The resultant product, a

[49]Ebasco Services, Inc., et al., "Final Volume II, Structures Profiles, Structures Survey Report, Section 2.7 Buildings 1402 - 1405; Buildings 1501 - 1512; Buildings 1601 - 1622; and Buildings 1701 - 1736 (North Plants) (Commerce City, Colorado: Rocky Mountain Arsenal, 1988), prepared for the U.S. Army Program Manager's Office for Rocky Mountain Arsenal Contamination Cleanup, Building 1402, 1403, 1404, 1405, 1501, 1502, 1503 A, B, and C, 1504, 1505, 1506, 1507, 1508, 1509, 1510, 1601, 1602, 1603 A and B, 1605, 1606, 1607, 1608-13 (hereafter cited as North Plants Structures). "North Plants" will be used in this report since this is the accepted reference to the nerve agent manufacturing facility.

mixture of methyl dichloro and methyldifluoro phosphine oxide ["Di-Di"; code initials "SC"], was established at the conclusion of Step IV.[50]

In Step V, the Di-Di reacted with isopropanol alcohol under controlled conditions of temperature, time, and vacuum. The reaction products were flashed [ Flash Chamber] to high vacuum [25 mm. of Hg absolute] and passed through a heated falling film tower to remove the hydrogen fluoride and hydrochloric acid. Through distillation, the reaction products were separated from the UY (Sarin). The agent was collected in product receivers, sent to a neutralizing tank for treatment with caustic to inactivate any acidity and pumped underground for storage in Building 1506.[51]

The equipment used in the Step V process included:

Horizontal heat exchangers shell and tube(Reactor Condensers)
Horizontal Hastelloy-B heat exchangers (Degas Condensers)
Horizontal Hastelloy-B heat exchangers (Preliminary Distillation Condenser)
Vertical carbon steel heat exchangers (Preliminary Distillation Reboilers)
Horizontal Hastelloy-B heat exchangers (Product Condensers)
Vertical carbon steel exchangers (Final Distillation Reboilers)
Horizontal carbon steel exchangers (Degas Distillation Scrubber NaOH Cooler)
Concentric double pipe carbon steel exchangers (General Vacuum NaOH Cooler)
Horizontal carbon steel exchangers (Reactor Scrubber NaOH Coolers)
Horizontal Hastelloy-B exchanger (Product Batch Still Condenser)

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[50]Hylton, "History of Chemical Warfare Plants," page 64 [microfilm 557]; Vitro Corporation of America, "Manual VI, Tank Farms", August 8, 1952, RMA 181, page 9, [microfilm 351], copy on file at Technical Information Center, Rocky Mountain Arsenal, Commerce City, Colorado. Monel is alloy of cupro-nickel with certain minor elements controlled to improve weldability , which is resistant to stress-corrosion cracking.

[51]" C. G. Purcell, et al., "Operating Manual for IOP Manufacturing," undated, RMA 151., pages 411, 470-472, 674; "Operating Manual GB Manufacturing," October 12, 1956, RMA 199, microfilm on file at the Technical Information Center, Rocky Mountain Arsenal, Commerce City, Colorado.

Vertical Hastelloy-B vessels (Reactors)
Four Flanged sections of Hastelloy-B (Degas Tower)
Vertical Hastelloy-B towers (Preliminary Distillation Columns)
Vertical vessels (Final Stripping Columns)
Vertical Hastelloy-B towers (Final Distillation Columns)
Vertical Hastelloy-B columns (Degas and Distill Scrubbers)
Vertical Hastelloy-B columns (Reactor Vacuum Scrubbers)
Vertical Hastelloy-B tower (Product Batch Still)
Vertical 160-gallon, monel vessel, with heating jacket (SC Head Tank)
Vertical 160-gallon, carbon steel tanks, with heating jacket (TB Head Tanks)
Vertical Hastelloy-B tanks (Delay Vessel)
Vertical Hastelloy-B tanks (Flash Chamber)
Vertical 1,085-gallon, Hastelloy-B tanks (Product Receivers)
Vertical 120-gallon, Hastelloy-B vessels (Preli minary Distillation Receiver)
Vertical 285-gallon, Hastelloy-B tanks (Residue Receiver)
Horizontal 8,000-gallon carbon steel tanks (Roof Tanks)
Vertical 1,085-gallon Hastelloy-B vessels (Neutralizer Tanks)
Vertical 150-gallon, carbon steel vessels (Stabilizer Weigh Tanks)
Vertical 2,005-gallon Hastelloy-B vessels (Decontamination Tanks)
Vertical 1,085-gallon carbon steel vessels (Filtrate Receiver Tanks)
Horizontal 3,000-gallon carbon steel vessel (TB Feed Tank)
Vertical 4,500-gallon, glass-lined, carbon steel vessel (Drain Catch Tank)
Vertical 250-gallon, glass-lined, carbon steel vessel (Pre. Distillation Run-Down Tank)
Horizontal 10,000-gallon carbon steel vessel (Product Run-Down Tank)
Hastelloy-B 1,085-gallon tank (Batch Still Receiver)
Hastelloy-B 325-gallon tank (Batch Still Heads Receiver)[52]

## FILLING OF MUNITIONS (1952-1955)

The filling of munitions with GB was done in Building 1601 [See HAER No. CO-21-DE], which was divided into three sections. The southern section of the structure was used as a preparation area for degreasing and cleaning shells prior to filling. The center

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[52]Purcell, et al., "Operating Manual for IOP Manufacturing," RMA 151, pages 411-421. Hastelloy-B was a corrosive-resistant nickel-based alloy.

section was used for the actual filling and three fully-automated machines and related equipment were installed there. The northern section of the building housed the paint operation, where filled munitions were painted, stenciled, and loaded onto pallets.[53]

By 1952 an automated pilot filling plant for 10-pound aerial bombs was nearly complete in Building 1601. The pilot filling machine had been redesigned so that it could handle not only the E54R6, Type A casing, but also the E54R6, Type B and E82R1, as well. Work was also underway on a pilot filling plant for shells and rockets designed to be similarly fully automated.[54] Full-scale filling operations began in 1953, including the M34 cluster (M125 bomb) and subsequently the 155 MM M 121 projectile, 105 MM M 360 cartridge, 8" M 456 projectile, and MK 116 "Weteye" bomb. The M34 Cluster contained 76 M-125 8.8 pounds bombs, loaded with 2.6 pounds of liquid GB. When the cluster was dropped, a wire was withdrawn from the arming fuzes, allowing the vanes on the fuzes to freely rotate. After a set number of rotations, each fuze detonated a burster charge which detonated the cluster ejection cartridges. This force opened the adapter and the M-125 bombs fell out, slowed by a parachute. On impact the burster exploded and dispersed the liquid GB agent. Filling and associated operations finally ended in 1969.[55]

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[53]North Plants, Building 1601.

[54]Hylton, "History of Chemical Warfare Plants", pages 62-63 [microfilm 555-556].

[55]North Plants, Building 1601; Melito and Moloney, eds., "Project Eagle Phase II, Demilitarization . . . of the M34," pages, 2-3, 2-5.

**INCENDIARY WEAPONS PRODUCTION:**

AN-M50 (1941)

The CWS, in 1941, took over refinement of Ordnance's AN-M50, a 4-pound, magnesium body bomb, filled with a ignitable mixture--therm-8. Therm-8 was a mixture of eighty percent thermite and twenty percent of the Ordnance Department's M8 flare mixture.[56] It was used by the British and required significant modification before it functioned well. The retooled AN-M50A2, with improved fuze and mixture, proved to be an effective weapon and, once the United States had obtained sufficient supplies of magnesium, mass production continued throughout the war. Almost 30,000,000 M50s were dropped in Europe and another 10,000,000 were used against Japan.[57]

CLUSTER BOMBS (1941-1944)

The CWS also initiated development for a multiple component incendiary, known as a cluster. This bomb consisted of individual 4-, 6-, and 10-pound projectiles held together by an "adapter." Work on adapters had been started by the Ordnance Department and was continued by the CWS when it took over the incendiary bomb

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[56]L. Wilson Greene, "Prewar Incendiary Bomb Development," *Chemical Corps Journal* (October 1947), page 30.

[57]Brophy, Miles, and Cochrane, *The Chemical Warfare Service: from Laboratory to Field*, pages 173-174. Fuzes types include: impact action, proximity, self-destroying, time, and variable time. *A Dictionary of United States Military Terms* (Washington, D.C.: Public Affairs Press, 1963, page 98. Wesley Frank Craven and James Lea Cate, *The Army Air Force in World War II*, Volume II, *Europe: Torch to Pointblank* (Chicago, Illinois: University of Chicago Press, 1949), passim.

program. The apparatus was made up of two end plates, two longitudinal bars, and four steel straps. The first adapter was known as the Model M5 and held together thirty-four 4-pound magnesium bombs. A subsequent adapter model, the M6, was used for 128 bombs. The first clusters were known as "quick-opening" types and were effective in low-level bombing situations. But when high altitude bombing became standard in about 1943 and used in multi-engine bombers like the B-25, they were replaced by "aimable" clusters, with adapters enclosed in a cylindrical case. The cases were also manufactured with a round nose and tail fin to improve flight characteristics and target accuracy. In operation a variable time fuze, based on a British model, detonated a strand of primacord and the resulting explosion burst the steel straps that circled the cluster. Slightly modified so that it could be used by both the British and United States Navy aircraft, this cluster, designated Model AN-M17A1, was used throughout the rest of the war.[58]

FILLINGS

The CWS also experimented with different filling mixtures. At first the CWS tried a mixture of gasoline and cotton waste. Tests showed that ordinary gasoline was useless as a filling and material was needed to thicken the petrochemical so as to make it burn slowly. The British had found that rubber could achieve this effect and the CWS

[58]Brophy, Miles, and Cochrane, *The Chemical Warfare Service: From Laboratory to Field*, pages 176-177. Green, Thomson, and Roots, *The Ordnance Department: Planning Munitions for War*, page 458.

effectively used various forms of this product. But, when the Japanese cut the flow of natural rubber, the CWS and NRDC initiated research and tests for substitute thickeners. Chemists at Du Pont Corporation achieved success with isobutyl methacrylate polymer (IM) and discovered that it would convert gasoline into a tough rubbery jelly. However, since there was a wartime shortage of IM because of its value in other weapons, other NRDC chemists at Arthur D. Little, Inc. and the Gibbs Laboratory, Harvard University began investigating the use of soaps as thickeners. The use of aluminum soap obtained by combining naphthenic and palmitic acids proved effective in converting gasoline into a thick jelly. The researchers thus decided to call their new thickener "napalm," a misnomer since the gelling quality is due not to the high content of palmitic but rather lauric acid.[59] The CWS used the new thickeners in developing an improved product called pyrotechnic or PT-1 fuel. PT-1 was manufactured by combining "goop," a mixture of magnesium particles and asphalt, with gasoline thickened with IM, oxidizing agents, and magnesium scraps.[60]

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[59]Green, Thomson, and Roots, *The Ordnance Department: Planning Munitions for War*, pages 259-452; Arthur B. Ray, "Incendiaries in Modern Warfare," *Industrial and Engineering Chemistry*, Volume 13 (1921), pages 645-646; Louis F. Fieser, et al., "Napalm", *Industrial and Engineering Chemistry*, Volume 38, Number 8 (1946), pages 768-773; E.W. Hollingsworth, "The Use of Thickened Gasoline in Warfare," *Armed Forces Chemical Journal*, Volume 4 (January 1951), pages 26-32; R.W. Hufferd, "Spectacular Developments Made In Incendiaries," *Chemical Engineering*, 53 (1946), pages 110-13; Noyes, *Chemistry*, pages 410-419.

[60]Brophy, Miles, and Cochrane, *The Chemical Warfare Service: From Laboratory to Field*, pages 179-180.

## M74 BOMB FILLING AND CLUSTERING PLANT (1942-1945)

All of these processes for manufacturing PT-1 were used at RMA in the M74 Incendiary Bomb Filling and Clustering Plant. The Plant consisted of eleven buildings: Mixing and Filling Building (328 [See HAER No. CO-21-AS]); Gasoline Unloading Pump House (329 [See HAER No. CO-21-AT]); Intermediate Magazine Building--Fuze Storage (336); and Intermediate Magazine--Powder and Primacord storage (339). The other seven buildings were converted warehouses and had multiple functions:

Building 341: Supply headquarters, wash rooms and locker rooms, and offices for Personnel, Inspection and Administrative staffs;

Building 348: Storage of M74 bomb casings and tail-cup assemblies; part of the Zig Zag conveyor to feed these parts to the Filling Building; maintenance and salvage shops.

Building 343: Used for final bomb assembly and preclustering. Bombs were inspected and painted; tails and fuzes were added, and the M-23 adapter was put in place.

Building 344: Used for final clustering. This operation included installing clamps, straps, and ballasts on the cluster. Cluster components were stored here, also.

Building 345: Clusters were "drop tested" in concrete chambers.

Building 346: Used for intermediate storage of packed, accepted clusters. [See HAER No. CO-21-AY]

Building 333: Used for storing and processing IM polymer.[61]

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[61]*RMA History*, Volume 9, Part 1, pages 2741-2744.

## PRODUCTION OF PT-1 (1942-1945)

In preparing the PT-1 material, drums of goop--a mixture of magnesium dust paste and impure magnesium dust protected from rapid oxidation by an oil-asphalt combination--were delivered to the "handling room" located in the Mixing and Filling Building (328). The contents were dumped into specially designed weighing hoppers , built by Havens Structural Steel Company, Kansas City, Missouri, transported to the second floor by hydraulic platform lifts made by Globe Hoist Company, Philadelphia, and dumped into one of four mixing machines located in Goop mixing cubicles. Magnesium required no further processing and was added in weighed amounts to the mixing machines. Sodium nitrate, however, required drying and this was done in a Proctor and Schwartz "hurricane" type, four-door, truck-tray drying unit. After drying, the nitrate was ground to specification and added to the mix. Another ingredient, Petroleum Oil Extract, a viscous phenol extract of petroleum, required heating before it went into the mixing machines.[62]

The "gel" required the mixing of IM, sometimes heated and ground in a comminuting machine, with heated gasoline (eighty-five degrees Fahrenheit). The IM and gasoline were combined in one of two cylindrical, jacketed kettles, manufactured by Industrial Process Engineers, New York City, equipped with agitator paddles. The gel was pumped into weigh hoppers on the second floor and added to the mixing machines. These machines were standard Baker-Perkins "universal" kneading and mixing units, with an

[62]Ibid., pages 2745-2746.

800-gallon capacity. About 100 gallons of the raw product were mixed by two counter-rotating concentric blades and the finished PT-1 was ready for bomb filling.[63]

## BOMB FILLING (1942-1945)

Robert S. Meyers, an engineer at RMA, designed the eight positive-displacement reciprocating type pumps. These pumps were used to fill the 10-pound M74 bombs which had been preassembled with casing, tail-cups and plug. They were delivered on a Zig Zag conveyor that originated in Building 348. After the PT-1 was delivered in a measured amount from the filling nozzle into the bomb casing, the white phosphorous tail-cup was re-inserted and pressed into the casings. The casings were then hand-fed to the crimping machines where the tail-cups were seamed. Finally, the tail-plug was tightened . There were two filling lines, with a capacity of eight bombs per minute, although the "line" sometimes produced as many as twelve bombs per minute.[64]

The filled bombs were placed into individual work-holders on the Ziz Zag and were sent into the bomb heating chamber, where they circulated until reaching a temperature of between 110 to 120 degrees Fahrenheit. This increased the internal pressure sufficiently so that any leaks would be noticeable. After leaving the heating chamber, the bombs continued on the Zig Zag into Building 343 where they were inspected and

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[63]Ibid., pages 2746-2748, 2751.

[64]Ibid., pages 2757-2758. White phosphorous will ignite spontaneously when exposed to air and thus help to ignite the filling.

transferred on to one of two conveyors of the two-pin, extended pin roller type, manufactured by Spro-Con of Chicago, Illinois. Each conveyor lead into automated spray-paint booths, where the bomb received a coat of lacquer, followed by marking.[65]

### TAILS AND FUZES (1942-1945)

The bombs were next loaded onto two parallel bomb assembly conveyors, which had individual work holders welded into the links at seven-inch intervals. These chain and sprocket conveyors were specially manufactured by the Rex Iron Works Company and Maclear Manufacturing and Supply Company, both from Denver. At the first work station tail assemblies--tails and springs--were loosely installed in the tail-plug. At the next station they were hand-tightened with wrenches and placed nose-up in the conveyor. Black powder bags were inserted next. Pretested fuzes were luted with white lead in one of the assembly booths. Next, the fuzes were inserted loosely into the nose threads of the bomb. At the next station the fuzes were tightened.[66]

### PRECLUSTERING (1942-1945)

Preclustering was the next operation and consisted of packing the M23 adaptor with M74 bombs, creating an E48 cluster. After fuzing, the bombs remained on the assembly conveyor until they reached the preclustering booths. There, a pre-assembled adaptor

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[65]Ibid., pages 2760-2761, 2773-2774.

[66]Ibid., pages 2774-2775.

had been roller conveyed from Building 344 and was adjusted for proper packing. Two operators worked in tandem. One person took a bomb from the conveyor, inserted a release bar over the release pin of the fuze, and placed the bombs end to end, fuzes forward, in the bottom cluster bar of the adaptor. After each bomb was properly placed, the safety wire was removed from the fuze. When the last bombs were in place the top adaptor components were replaced and fitted, after which a strap was clamped around the cluster to temporarily secure it.[67]

## FINAL CLUSTERING (1942-1945)

The bombs were transferred to a final clustering conveyor--manufactured by Matthews Conveyor Company of Ellwood City, Pennsylvania-- located at the entrance of the corridor connecting Buildings 343 and 344. When the clusters arrived in Building 344, the permanent clamp assemblies were installed around each bomb and the temporary straps were removed. Nine straps were then added and tail and nose ballasts were installed The bomb was transferred to powered rollers and delivered to the drop-testing room. At this point the cluster rolled down an inclined section of conveyor and impacted against a steel plate inside a drop-test chamber. If any of the M74 bombs did not function correctly, the chamber was flooded and fog was introduced to extinguish any possible fires. After the drop-test, the cluster was visually inspected and any loose straps replaced. Tail fin assemblies were installed and finally pre-cut lengths of primacord

[67]Ibid., pages, 2776, 2884.

were threaded into the cluster.[68] Three additional straps were then placed around the cluster and two bags, each containing five pounds of Briocel were tied to the unit. The shored clusters were sealed into specially designed drums that were pressure sealed and transported by lift trucks to Building 346, where they were stored temporarily by lots.[69]

M47 INCENDIARY BOMB PLANT (1942-1945):

· BACKGROUND (1937-1940)

The M47, a 100-pound bomb, was originally designed by the Ordnance Department in 1937, and they completed tests on it in 1940.[70] Since the military had no incendiary bomb at that time, Ordnance recommended its use as chemical weapon and began experimental drops using ordinary gasoline and cotton waste. When the CWS took over incendiary bomb development, they confirmed the problems and successfully completed work to combine gasoline with suitable thickeners--either IM or napalm.[71]

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[68]Ibid., pages 2761, 2786-2788.

[69]Ibid., page 2806.

[70]The AN-M47-A2 was a 72-pound bomb, containing 40 pounds of gasoline gel; it used an M12 burster, consisting of black powder and magnesium powder; and it had a nose impact M-126A1 or M-108 fuze ; the AN-M47-A3 was a 73-pound bomb, containing 40 pounds of gasoline gel; it used an M13-M9 burster-igniter, a mix of white phosperous, TNT, and a tetryl; and it had a nose impact M-126A1 or M-108 fuze. Office of Scientific Research and Development, National Defense Research Committee, Division 2, *Summary Technical Report of Division 2, NRDC, Volume 1, Effects of Impact and Explosion* (Washington, D.C.: National Defense Research Committee, 1946), page 366 (hereinafter cited as *Effects of Impact and Explosion*).

[71]Brophy, Miles, and Cochrane, *Chemical Warfare Service: From Laboratory to Field*, pages 168-169.

## CONSTRUCTION (1942-1945)

Napalm was used in the RMA M47 Incendiary Bomb Filling Plant (IOB). [See HAER No. CO-21 drawing 4 of 13 "Chemical Production" Distilled Mustard Gas and Incendiary Bomb Facilities-1945."] Preliminary engineering and architectural studies for the IOB commenced early in December 1942. The first construction work started in January 1943 and the plant was ready for operation on April 1, 1943. The various buildings and their functions are summarized below: [See HAER drawing 5 of 13 "South Plants-1945"]

| | |
|---|---|
| Building 741 | Napalm Warehouse; Mixing and Pumping Rooms |
| Building 742 | Empty Bomb Warehouse; Bomb Filling Room; Filled Bomb Storage [See HAER No. CO-21-AE] |
| Building 743 | Office and Change House |
| Building 744 | Pump House [See HAER No. CO-21-CF] |
| Building 745 | Gasoline Storage Tanks (2) |
| Building 746 | Gasoline Unloading Rack |
| Building 747 | Cafeteria |
| Building 748 | Paint Storage Warehouse [See HAER No. CO-21-CG] |
| Building 749 | Fuze Magazine |
| Building 751 | Surveillance Magazine (completed in July 1943) [See HAER No. CO-21-CH] |
| Building 752 | Surveillance Magazine (completed in July 1943)[72] [See HAER No. CO-21-CI] |

## PRODUCTION OF NP GEL (1942-1945)

To manufacture NP (napalm) gel, also known as "incendiary oil," "thickened gasoline," or simply "gel," 500 pounds of napalm was dumped into a hopper installed above the mixing kettles constructed in the Mixing and Pumping Rooms of Building 741.

[72] *RMA History*, Volume 4, part 1, pages, 1074, 1077.

There were three 1,000-gallon kettles built by the Winter-Weiss Company of Denver in accordance with designs prepared at RMA. These kettles were seventy inches in diameter by ninety-eight inches deep, with concave bottoms and heads. Double-action paddle agitators were installed in each kettle, powered by a fifteen-horsepower motor. Approximately six hundred gallons of temperature-controlled gasoline was pumped directly into the kettles. The agitator was started and the previously measured hopper amount of napalm were added. The mixing continued until the napalm was uniformly dispersed and the thickening action had proceeded to the point where the napalm particles settled.[73] "Gel" pumps directly connected to the kettles transported the NP gel from this processing equipment to the Bomb Filling Room located in Building 742. Viking rotary-gear pumps were first used but these pumps could not handle enough product and they were replaced by "Moyno" type screw pumps manufactured by Robbins & Myers, Inc., Springfield, Ohio.[74]

## FILLING OPERATIONS (1942-1945)

Empty bomb casings still in their packing boxes from either incoming carload shipments or from storage piles in the Empty Bomb Warehouse (742) were placed on the empty bomb conveyor. Workers received and opened the boxes and the empty casing was hung by its tail on the overhead transfer conveyor. Another worker removed

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[73]Ibid., volume 9, part 2, pages 2967, 2969, 2971, 3010-3011.

[74]Ibid., pages 2972-2975.

the casing and placed it tail-down on a filling pallet. The burster well was unscrewed from the nose and the well was removed from the bombs and the threads luted with white lead. The casing was placed on a gravity roller conveyor and was positioned for filling with about sixty-two pounds of NP gel. After checking the bomb's weight, a burster well was inserted and tightened. A handling ring was then attached to the head of the burster well, and the bomb was hung on the painting and marking conveyor. As the bomb passed through the automatic paint spray booth, it was given a coat of olive-drab lacquer. This coat dried as the bomb moved along the conveyor and the bomb then passed through the printing machine, where the proper markings were applied. The finished bomb was inspected and placed into a stencilled packing box. The handling ring was removed and the box was closed and sealed with steel straps. The packed bombs were stacked on pallets in Building 742 while awaiting shipment.[75]

"REWORKING" M69 BOMBS (1942-1945)

RMA was also assigned the task of "reworking" M69 bombs, a 6-pound, steel case bomb filled with thickened gasoline.[76] The bomb had been developed as a

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[75]Ibid., pages 3011-3013. As noted above, the weapons data published after the war by the National Defense Research Committee showed that the filling was 40 pounds rather than the 62 pounds actually used at RMA.

[76]The AN-M69 was a 6.2-pound bomb, designed to be filled with 2.6 pounds of gasoline gel; it used a charge of black powder and magnesium powder, and a nose inertia M1 fuze. It was employed as 500-pound amiable and 100- and 500-pound quick-opening clusters. *Effects of Impact and Explosion*, page 366.

collaborative effort between the NRDC and the Standard Oil Development Company. The bomb was designed to act like a small mortar and ejected a single blob of filling several yards. To achieve this result, the designers placed a small powder charge in front of the filling. The bomb also used cloth ribbons as stabilizers instead metal fins. After some modifications, the bomb became a potent weapon and it was believed that more than ninety percent produced ignited gasoline upon impact.[77] An M69X Bomb Filling and Clustering Plant was constructed at RMA, but was not completed before the end of the war and so the bombs were never manufactured. It was expected that M69X bomb casings would be filled with either napalm or PT-1. [78]

The Bomb Assembly Branch (BAB) was established at RMA to handle the "reworking" of M69s assembled into 100- pound and 500-pound clusters. The problem arose from the fact that the waterproof paper liners had failed during long-term exposed storage, resulting in the rusting of adapter parts and the decomposition of the cloth tails. So, the initial program was designed around the "declustering of the bombs, removal of the fuzes and "powder boats" and the cloth tails, as well. The bombs would then be rebuilt with new powder boats and fuzes, tails, and reassembled as E46 clusters. A production schedule was received from CWS headquarters in November 1943 and

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[77]Brophy, Miles, and Cochrane, *The Chemical Warfare Service: From Laboratory to Field*, pages 184-185.

[78]*RMA History*, Volume 4, part 2, pages 1124-1172, passim. The M69X was a 7-pound bomb, filled with 2.2 pounds of gasoline gel, with a charge of black powder and magnesium powder, and a nose inertia M142 fuze. *Effects of Impact and Explosion*, page 366.

cancelled the next month. The program was started and stopped repeatedly until the end of the war and BAB frequently changed jobs during this time. Work on the first clusters finally started in March 1944, in Building 333, with buildings 334 and 335 used for storage. The BAB effort was terminated in May 1944, after having reworked 356,440 bombs.[79] BAB was also given the task of modifying M13 clusters so that cluster components would not wash back into the bombers, causing the loss of both aircraft and the air men. The work was carried out according to CWS directive and consisted of wiring each cluster bar and suspension bar to the rear end plate as well as wiring the front end plate to the cluster bar. BAB completed this work on nearly 50,000 clusters before the program ended.[80]

PHOSGENE SHELLS (1942-1945)

RMA also filled casings with phosgene, a "choking" agent that produces irreversible pulmonary damage and resultant respiratory distress, often fatal. It was first employed in World War I and became the principal nonpersistent gas of that conflict. At the beginning of World War II, the CWS adopted it as their standard nonpersistent chemical filling for mortar shells and bombs.[81] The CG [Phosgene] Plant included the

[79]*RMA History*, Volume 9, part 2, pages 3052-3065, passim.

[80]Ibid., page 3066-3068.

[81]Compton, *Military Chemical and Biological Agents: Chemical and Toxicological Properties*, pages 111, 118-121; Office of Scientific Research and Development, *Chemical Warfare Agents, and Related Chemical Problems*, page 17.

filling operation (Building 331 [See HAER No. CO-21-AU]) and storage (Building 332). A caustic scrubber tower was constructed outside of the south wall of the filling building to absorb CG fumes and a rack for CG cylinders was installed near the northwest corner. The major equipment used in the operation was a monorail conveyor with eighteen half-ton hoists, paint spraying equipment, filling equipment, and refrigeration equipment for chilling the CG prior to filling the casings.[82] The Plant operated from January through December 1944 and filled 22,766 one-thousand pound casings and 2,020 five-hundred pound casings.[83]

### WHITE PHOSPHOROUS CUPS/IGNITERS AND CHLORINATED PARAFFIN (1942-1945)

RMA was involved, too, in the manufacture of white phosphorous cup and white phosphorous igniters. Near the end of the war, the Denver arsenal was requested by headquarters to modify facilities to meet the urgent demand for 42 percent chlorinated paraffin. The substance was used to mold- and fire-proof clothing. Due to the urgent demand from the Quartermaster Corps, production was started in the Thionyl Chloride Plant and subsequently transferred to Building 511 [See HAER No. CO-21-BK] and

[82] *RMA History*, Volume 8, pages 2708-2709.

[83] Ibid., page 2721.

511A. Some 960 tons of forty-two percent chlorinated paraffin were produced before the plant shut-down in June 1945 after completing the Quartermaster order.[84]

[84]Ibid., Volume 2, part 2, pages 473-479, Volume 3, part 2, pages 879-885, Volume 8, pages 2565-2566.

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